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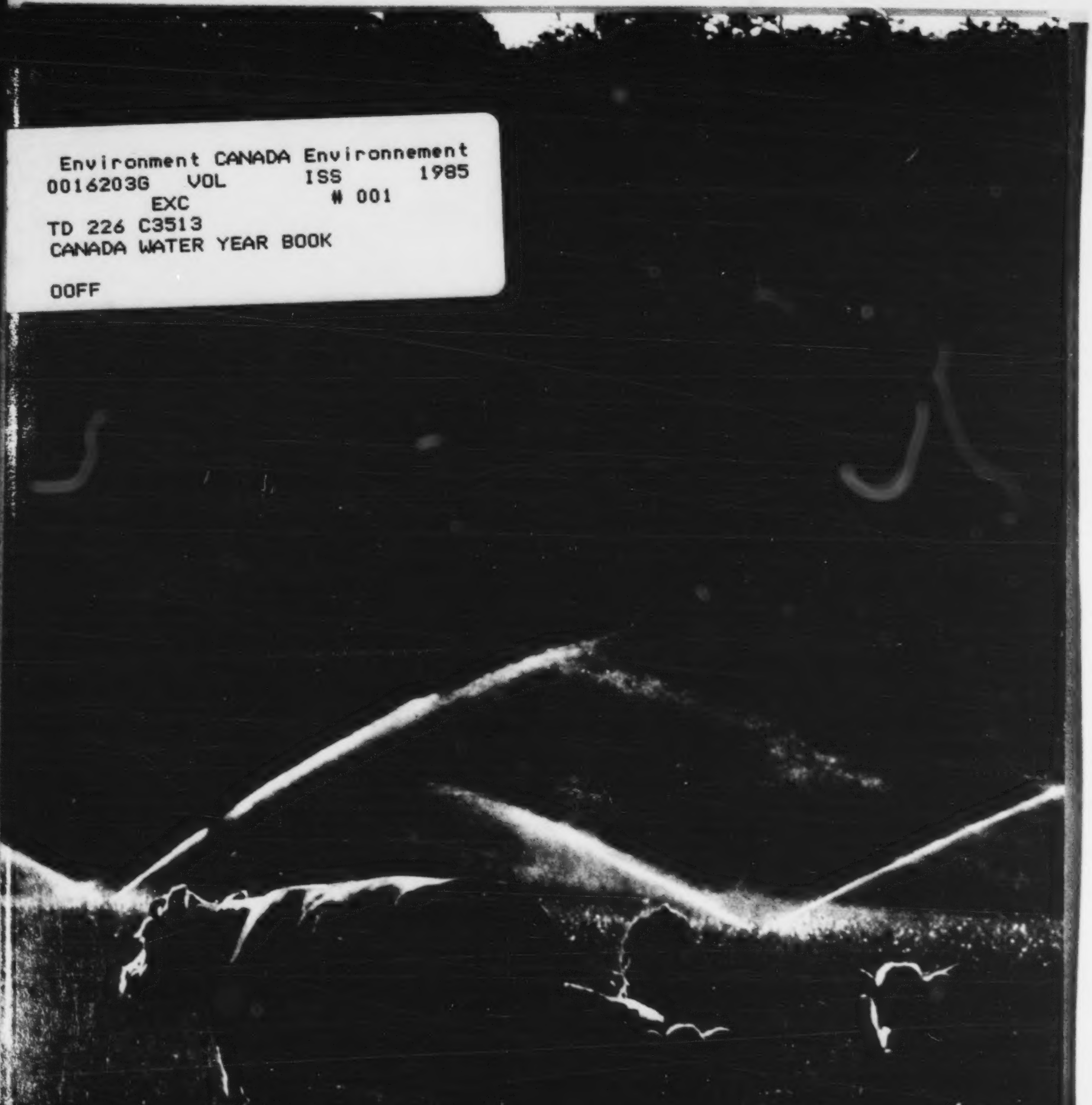

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Canada Water Year Book

1985

Water Use Edition

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Canada Water Year Book Series

Edition	Year Published	Principal Theme
First	1975	Broad general coverage on water
Second	1976	Water Management in Canada
Third	1978	Water Data Collection and Dissemination
Fourth	1980	Water Research in Canada
Fifth	1982	Water and the Economy
Sixth	1985	Water Use in Canada

Preface

This edition of the Canada Water Year Book is the sixth in the series reporting on freshwater resources in Canada. Details on each of the six volumes appear on the facing page.

The theme for this edition, Water Use in Canada, has been dealt with to varying degrees in most of the Year Books, in particular, the 1975 Year Book. As revealed later in this current edition, the water use data have been derived from actual surveys of industry, agriculture, municipalities, etc., together with estimates for non-respondents. With several industrial surveys to draw upon, it has become evident that earlier estimates were not all reliable and alterations have had to be made to most categories of water use. For this reason, data for earlier years (1976 and 1972) have been recalculated and appear herein with the latest survey data (for 1981). Accordingly, the data in this Year Book should be used in preference to those in earlier Year Books.

After briefly introducing new data for earlier years, this edition highlights all withdrawal uses as well as most non-withdrawal uses for 1981.

After each edition of the Year Book is released, it is made available in Canada through the Canadian Government Publishing Centre or authorized booksellers. Some earlier editions of the Year Books, which are not available through bookstores, may be obtained from the Director, Water Planning and Management Branch, Ottawa, Ontario, K1A 0E7.

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CALENDAR OF EVENTS

Inquiry on Federal Water Policy

On January 26, 1984, the federal Environment Minister announced the appointment of an Advisory Committee to conduct an Inquiry on Federal Water Policy. In brief the Committee was instructed to identify and describe emerging water issues and their federal policy ramifications. Subjects of study included the adequacy of the supply and quality of water in Canada as well as the suitability of scientific and research expertise in water management. Based on its findings, the Inquiry made recommendations and, as well, proposed strategies that the government could adopt to implement the recommendations. After meeting with representatives of the federal, provincial and territorial governments, the three members of the Inquiry conducted regional hearings across Canada followed by a national hearing in Ottawa early in December 1984. An interim report was prepared and released in April 1985 containing a synthesis of the opinions expressed during the hearings. About 20 authoritative accounts of the various subjects of investigation were completed by various experts to provide the Inquiry members with an overview on these subjects. The findings and recommendations of the Inquiry were prepared and presented to the Minister of the Environment shortly after the end of July 1985.

Federal-Provincial Cooperation

The national Flood Damage Reduction Program, a cooperative undertaking of the federal government and most provinces across Canada, has continued beyond the ten-year program originally envisaged. As a result, most of the joint Mapping Agreements and General Agreements have had to be renegotiated and reviewed or amended and special Studies Agreements and Flood Forecasting Agreements have been introduced. By May 1985, 46 areas had been designated under the formal Mapping Agreements involving some 300 communities with populations totalling about 6.8 million. As well, there has been considerable activity associated with federal-provincial Implementation Agreements to prevent flooding through the provision of structural works.

In March 1982, in response to requests from some provinces, the federal cabinet approved a new program providing for federal-provincial cost sharing agreements for water quality monitoring networks. Subsequently, Environment Canada has been negotiating water quality monitoring agreements with interested provinces to provide for sharing of costs, exchange of data and a Canada-wide quality control program. At the time of writing, a Canada-Quebec Agreement had been signed, negotiations with Alberta, Newfoundland and British Columbia had been completed and discussions with New Brunswick and Manitoba were under way. The agreements are modelled after the hydrometric agreements, with financing being provided by each government in proportion to its data needs.

In August 1984, both a Technical Report and a Summary Report were released highlighting the studies undertaken and recommendations made by the Canada-Ontario Study Committee to deal with the problem of mercury in waters and sediments of the Wabigoon-English River system in Northwestern Ontario.

Early in 1983, the governments of Canada, Ontario and Quebec established the Ottawa River Regulation Planning Board to plan and recommend criteria for regulating the Ottawa River, taking into account hydroelectric production, flood protection, navigation, low water problems, water quality needs and recreation. In a related but separate undertaking in 1983, the three governments set up the Ottawa River Water Quality Coordinating Committee to review and modify a proposed water quality monitoring plan for the Ottawa River and oversee its implementation, to undertake or recommend special studies as needed, and to recommend water quality objectives for the river.

In September 1983, the Canada-Quebec ecological inventories program, initiated in 1978-79 on rivers flowing into the St. Lawrence River and Gulf from its north shore, was completed. This program was designed to facilitate assessments of ecological impacts from future developments along the north shore.

The Mackenzie River Basin Committee representing Alberta, Saskatchewan, Manitoba, the federal government and the two territories, undertook a study of the water and related resources of the basin and released its report in 1982. The nine recommendations in that report are now being addressed by the Committee.

A Special Recovery Projects Program was announced in the federal budget of April 1983 to provide for federal financial contributions for water supply and sewage treatment projects at Niagara Falls, Sudbury and Timmins in Ontario. Its purpose was to stimulate the economy by contributing to capital projects which would otherwise be conducted at a much later date. By early 1985, the federal government contributed about $9.5 million to the three projects, approximately one third of their combined cost.

The federal government is also contributing one third of the total cost up to a maximum of $5 million under an ERDA Subsidiary Agreement towards construction of a granular activated carbon water filtration plant to service Regina and Moose Jaw, in Saskatchewan. The plant commenced operation in June 1985, while an associated carbon regeneration furnace and waste disposal lagoon are scheduled for later in the year.

An ERDA agreement was being negotiated with Newfoundland early in 1985 for the provision of federal funds towards the construction of a new water purification system for the town of Channel-Port aux Basques.

The $2.2 million Canada-Yukon Territory-British Columbia Yukon River Basin Study that began in 1980 drew to a close with release of the final report in mid 1985. The study has led to the formulation of a planning framework under which development alternatives in the Yukon basin can be evaluated.

Since 1971, Canada and Ontario have renewed the Canada-Ontario Agreement on Great Lakes Water Quality in 1976 and again in 1982 to reflect Canadian commitments under the Canada-U.S. Agreement on Great Lakes Water Quality. Because the agreement expires in 1985, negotiations have been under way to extend the agreement, to step up water quality surveillance, and to include the Phosphorus Management Plan which in the past year was incorporated in the International Agreement.

Early in 1985, an agreement was being negotiated by Environment Canada, the Department of Fisheries and Oceans, representatives of British Columbia, and two Harbour Commissions to implement a Fraser River Estuary Management Plan. The agreement calls for the setting up of a

Management Committee Executive representing the five negotiating parties, and a larger Management Committee representing these same five parties and other management organizations in the Fraser River basin.

A three year Canada-Saskatchewan South Saskatchewan River Basin Study has been proposed. In mid-1985, the terms of reference for the study were being reviewed by the Saskatchean Water Corporation and Environment Canada.

The creation of the Canadian Heritage Rivers System was announced on January 18, 1984. The program will give national recognition to rivers which are significant examples of Canada's natural environment, as well as those which have played an important role in Canadian history or which offer outstanding recreational opportunities. After designation, each river will continue to be owned by the government originally having jurisdiction over it but, by joining the program, that government agrees to manage the designated river in a way that will ensure its distinctive heritage values are protected and opportunities are provided for public use and enjoyment.

Following acceptance of the report of its Task Force on Water Quality Guidelines late in 1984, the Canadian Council of Resource and Environmental Ministers has arranged for the publishing of "1984 Inventory of Water Quality Guidelines and Objectives" as well as the document "Canadian Water Quality Issues". Work is continuing on the need for harmonized guidelines for water quality uses across Canada and on the production of a compilation of research needs relating to water quality guidelines and objectives.

International Cooperation

Since 1972, Canada and the United States have been cooperating under an International Agreement to improve the quality of the water in the areas of the Great Lakes now suffering from pollution. Programs to control and prevent pollution from industrial sources from entering the Great Lakes System have been designed and are being implemented. A commitment has been made to eliminate the discharge of toxic substances into the Great Lakes. New interim phosphorus loading targets, defined for each lake, are designed to achieve desirable levels of water quality.

In December 1984, a special U.S. Commission proposed a plan for the Garrison Diversion Project which promises to lead to a satisfactory resolution of longstanding Canadian concerns over transboundary impacts. The governments of Canada and Manitoba have for a long time expressed concern that return flows from Garrison Diversion, if developed as originally planned, could result in a transfer of foreign biota northward into Manitoba. The U.S. Commission recommended that the majority of features which were objectionable to Canada be abolished and that consultation between Canada and the United States be continued. Congressional consideration of the Commission's recommendations may take up to one year. Meanwhile, construction is being governed by recommendations of the special Commission.

In April 1985, the International Joint Commission released its report dealing with diversions and consumptive uses of water in the Great Lakes region of both Canada and the United States. A Canada-Ontario Working Group on Great Lakes Water Apportionment is being established to review policy implications of this report and several other related issues.

A Canadian coal development in the Cabin Creek region of the Flathead River Valley in British Columbia has raised concern in the United States over possible transboundary pollution affecting air, wildlife and water quality. Early in 1984, joint discussions regarding the development took place between Canada and U.S. officials and, in February 1985, the two governments requested that the International Joint Commission look into the potential effects of the proposed mine development on the waters of the Flathead River.

The framework agreement between the Province of British Columbia and the City of Seattle has been implemented and the means for British Columbia to prevent further flooding across the International Boundary and into the Skagit River valley is in place. The Province earlier gave Seattle the right to raise the forebay of its municipal hydro plants, allowing additional flooding in Canada. It has since negotiated an agreement altering the earlier agreement but, by doing so, has committed itself to supply power to Seattle for an agreed period, at an agreed cost and in an amount equivalent to the power foregone at the Seattle (Ross Dam) hydro plant.

Other Water Management Activities

In a move to improve upon data collection associated with the hydrometric survey, a five-year program to acquire and install 350 data collection platforms (DCPs) at remote hydrometric sites across Canada has been under way since April 1983. Through the use of satellites, the DCP permits the real-time acquisition of hydrometric data. Effectiveness of operation and cost saving were key items in the original proposal, with the output of greatest value to navigation, reservoir operation, water allocation, flood forecasting and similar purposes. When necessary, DCPs are being equipped with sensors to provide information required by the Atmospheric Environment Service and the Canadian Forestry Service.

Since 1982, Environment Canada has been coordinating research on water supply constraints to energy development on behalf of the Department of Energy, Mines and Resources. The project involves research on a model for forecasting the time series of future water needs for the major water sectors of the Canadian economy. It includes an agricultural sub-routine which takes into account irrigation demands based on climatology. The research is currently being extended to the major energy production areas of the Prairies and to preliminary development of the model's database for the entire Saskatchewan-Nelson basin; a demonstration analysis has been made for the Red Deer River basin in terms of energy, irrigation and interprovincial flow apportionment; to follow will be the calibration of larger areas.

Significant Meteorological and Hydrological Events in Canada 1983 and 1984

Meteorological Highlights – 1983

The year 1983 will be remembered for having both a mild winter and a summer of near perfect vacation weather. However, the picture was somewhat spoiled by heavy winter rains on the West Coast and a summer drought on the Prairies and in parts of Ontario and Quebec.

Temperature – The year as a whole had generally above normal temperatures of 0.5 to 1.4 deg across southern Canada, but in the Yukon Territory and over northern Quebec, in Labrador and the eastern Arctic, the weather was cooler than normal. Baffin Island was especially cold with the year-long mean temperature between 1.0 and 3.0 deg below normal.

Southern Canada experienced record warmth from December 1982 through February 1983. Temperatures in southern Manitoba were the mildest in over half a century. There was a dearth of snow with seasonal accumulations being about half the normal from British Columbia to Quebec. Many southern Ontario sites had their lowest seasonal snowfall since records began; Montreal's seasonal snowfall of 69 cm was only 36% of normal. For skiers or resort operators in Quebec or Ontario, the winter was one of the worst in years.

Precipitation – Annual precipitation totals exceeded normal amounts over the Arctic Islands, along the British Columbia coast and in the British Columbia southern interior, across a large portion of the northern Prairies, over most of the southern region of Ontario and Quebec, and in Atlantic Canada. Lighter than normal totals occurred across the southern Prairies, most of British Columbia and the Yukon. The driest region, with annual precipitation totals only 50 to 70% of normal, was in southern Manitoba and southwestern Alberta; the wettest region, above 200% of normal, was along the southern coast of Newfoundland.

Storms – There were disastrously heavy winter rains on the West coast, mud slides north of Vancouver and equally bad storms on the Atlantic coast. In central Newfoundland, 250 mm of rain fell during three days in January causing millions of dollars of damage in a dam burst on the Exploits River. The Prairies had blizzards as late as mid-May when nearly 50 cm of snow fell south of Regina in one day, the worst in half a century. On May 2, at least eight tornadoes ransacked southern Ontario causing multi-million dollar property damage and leaving many residents homeless in Lambton County. The town of Reeces Corners, east of Sarnia, was nearly demolished by the violent winds. In June, the Prairies had several days with severe weather – tornadoes, sudden downpours, large hail and strong winds. On one June day, Saskatoon had 100 mm of rain 75 mm in one hour – a once in a hundred-year occurrence. Major storms lashed the East Coast during November and early December; winds in excess of 100 km/h caused property damage in the millions of dollars. A late November wind storm left two-thirds of New Brunswick without electricity. Finally, a mid-December snow storm, the worst in five years, brought Ottawa, the nation's capital, to a standstill. This same storm struck Quebec, causing a ship to sink in the St. Lawrence River, and downing many power lines under the weight of freezing rain.

Meteorological Highlights – 1984

On average, most Canadians experienced warmer than normal temperatures during 1984. The southern Prairies in particular were affected with a major drought occurring during the spring and summer. South of a line, from Calgary through Saskatoon to Brandon, nearly 50% of the grain crop was lost as the area suffered through its poorest growing season since the drought of the 1930s. A localized drought of lesser proportions was experienced in parts of Nova Scotia during the fall.

Temperature – Some cooler temperatures were experienced mainly in northern Newfoundland, Labrador, the Arctic Islands, southwestern British Columbia and parts of Alberta. However, these annual averages conceal the fact that Western Canada enjoyed mild conditions from January through April with temperatures as much as 10°C warmer than normal for the time of year. The contribution of this period to the annual statistics was overbalanced later in the year by the abnormally early onset of winter in the west. Killing frosts were reported by the end of September in the interior valleys of British Columbia while at the same time cold weather with snow moved over the Prairies. Record cold October temperatures and snowfall were reported from parts of British Columbia, Alberta and Saskatchewan. During November, temperatures were as much as 20°C colder than normal for the time of year in northern Alberta, northern British Columbia and the Yukon. An unusual reversal of temperature trends occurred in Ontario and Quebec during February and March. At a number of locations in Ontario, February 1984 was the mildest since records began thanks to a long stretch of above freezing temperatures. During this period temperatures rose to record levels as high as 15°C. On the other hand, March was the coldest in 25 years in parts of southern Ontario and Quebec, and on average was colder than February for the first time in more than a century of weather records.

Precipitation – During 1984, four main regions of precipitation deficiency were identified, namely (a) southern Alberta and southern Saskatchewan, (b) northwestern Quebec and adjacent Labrador, (c) central Baffin Island, and (d) the Yukon. The greatest deficiency was centred on the Regina and Moose Jaw area of Saskatchewan which received as little as 64% of its average yearly total of rain and snowfall. In contrast, surrounding areas stretching in a curve from Brooks, Alberta to Prince Albert, Saskatchewan, to southeastern Manitoba received abundant precipitation ranging up to 140% of normal. Most of British Columbia, and the northeast part of the Territories also received above normal amounts.

Storms – British Columbia suffered damaging windstorms in the spring and fall in which a number of lives were lost at sea. One, on April 15, produced gusts as high as 124 km/h at Terrace. Another on October 11 and 12, was the rejuvenated remnants of typhoon Ogden and produced sustained winds of 100 km/h with gusts to 165 km/h and gave heights estimated at more than 10 metres. Perhaps the most notable of the winter storms which lashed the country was the storm of February 28-29 which dumped record two-day snowfalls of up to 60 cm on parts of southern Ontario and 40 cm along the St. Lawrence Valley in Quebec. At least six traffic related deaths were attributed to this event. On April 15, the worst ice storm since 1958 hit Newfoundland and glazed utility lines with ice nearly 25 mm thick. Power outages left 200,000 people without electricity or heat. The same storm produced snow elsewhere in the Maritimes with Moncton reporting 90 cm.

Anyone who has been thirsty knows how important water is to human life. Without it, human life cannot be sustained, nor can the livestock, fish or plants on which man depends.

Beyond these vital necessities, water helps in many ways to improve our lives. It assists in personal cleanliness, flushes away the wastes of communities and helps put out fires, to name only a few.

Life's pleasures owe much to water. Nature's waterways offer swimming, boating and sport fishing, and support wildlife as well as the vegetation that makes our surroundings livable and attractive.

From earliest times, waterways carried the commerce of nations, and falling water supplied power. Later, industry found water valuable as both solvent and coolant. Now, new products and processes are making these industrial needs vastly greater than ever.

It can be argued that it makes no difference what water is used for or how it is used. Actually, the way that water is used is important because some uses borrow water from the natural cycle for longer periods than other uses, and there are significant differences in how and where the water is returned.

Many uses do little to disturb nature's cycle. In its natural habitat, water goes its way relatively unaffected by sailing and swimming. Natural water supplies such as these help to breed fish and support waterfowl and other forms of wildlife. For that matter, most Canadian farms are dependent entirely on rainfall and, in this way, use water without removing it from its natural cycle.

Many uses represent the most trifling borrowings and do not significantly affect the immediately available water resources of the region. Water merely passes through hydro plant turbines and steam plant condensers. In a turbine, only the potential energy of water changes but large hydroelectric developments can have a significant impact on the hydrologic cycle and the environment in general. In a condenser, as in many industrial cooling processes, only water's temperature changes, but the increased evaporation resulting from the discharge of such heated water back to the natural sources is becoming a growing

Life's pleasures owe much to water in one form or another.

problem. Such heating also presents a pollution problem because it may reduce the dissolved oxygen content of the stream below minimum levels thus damaging fish life.

Far more critical are the uses that reduce a region's immediate water supply. Much irrigation water, for example, goes back to the atmosphere by evaporation and transpiration. Thus, the farmer whose sprinklers operate on well water may cause a net reduction in his region's ground water supply. The same is not true, however, of the factory owner who installs a recharge well and returns much of his withdrawn water to essentially the same place in the cycle.

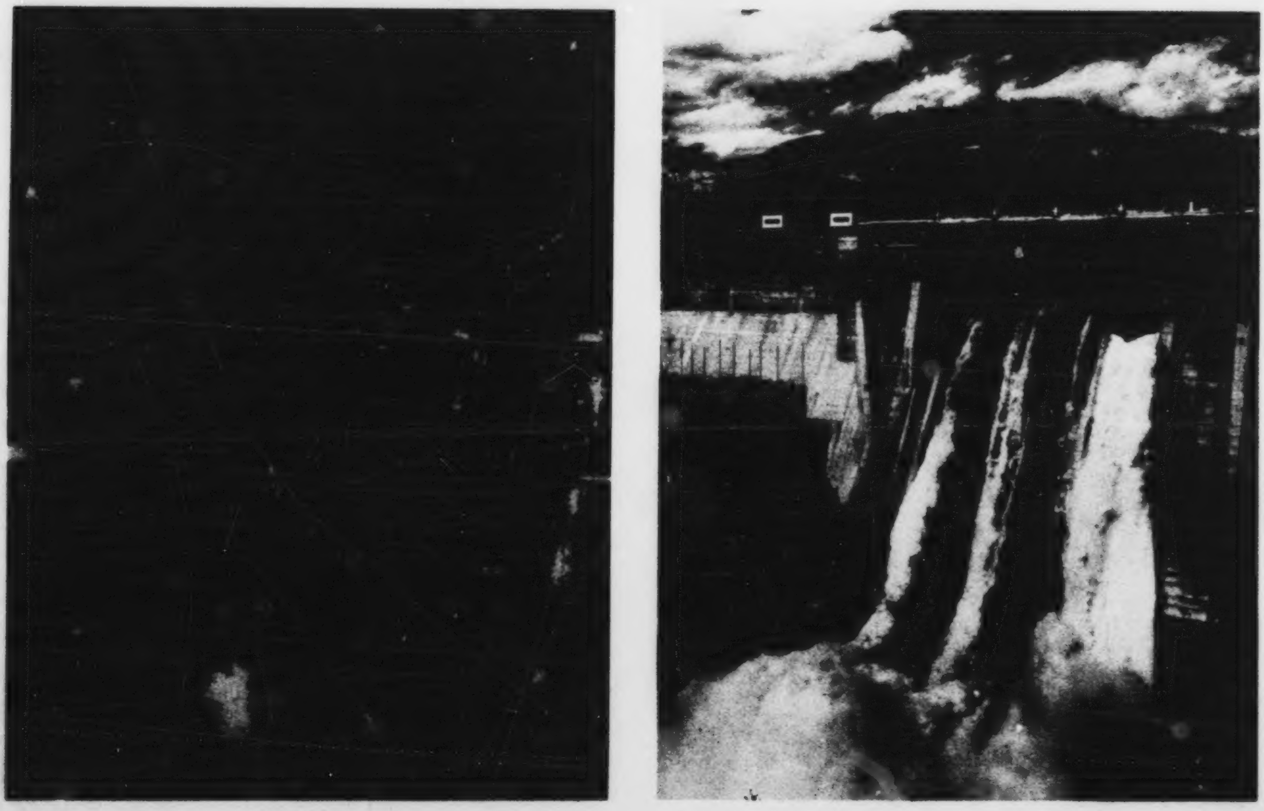
The state in which water returns to a source also makes a big difference. Municipal water systems withdraw water from a stream and municipal sewer systems discharge back into it. If these waste waters and those of industries using the stream are treated, and the water is returned to source, the available water supply is not greatly diminished but the cost to maintain its quality can be considerable.

Withdrawal use is most commonly discussed in terms of intake and consumption. Water intake is a measure of the amount withdrawn from the watercourse for a particular activity. This measure is important because it represents the demand imposed by that particular activity on the water resources at that given location. Usually, however, most of the water withdrawn is returned to the watercourse. Thus, in an overall supply-demand balance for that area, water intake is not the salient factor. What is important is the amount of water actually used up, or not returned to the source, that is, the amount consumed. Because the water cycle is a closed system when looked at in global terms, water is never actually lost. For example, water evaporated from industrial cooling towers becomes part of the atmosphere, later to fall as precipitation, thereby rejoining the water in and on the earth. But while this precipitation may fall near its point of evaporation for reuse locally, it is more likely to go elsewhere.

Other measures of withdrawal use are recirculation, gross water applied, water discharge and water consumption. Recirculation pertains to water that leaves a particular process and re-enters it or is used in another process before being discharged back to the source. Recirculation is most common in certain industrial operations such as pulp and paper production, petroleum refining and steel making. Gross water applied is the total amount (intake + recirculation) of water used. Water discharge is the amount of water returned to the source from the distribution system. Water consumption refers to water that is not returned to the source but is lost through evaporation or other use.

This Year Book will tend to stress the quantity side of water use but we are mindful of the fact that there are many instances of drinking water supply, agricultural use and fisheries use where quality consideration, not the quantity, is the limiting factor in the water's use.

The section that follows briefly describes trends in water use over the years from 1972-1981. Thereafter, the water use data for 1981 are dealt with in some depth.



From earliest times, waterways have carried the commerce of nations and falling water has supplied power.

Water Use Trends 1972-1981

Until recently, efforts at collecting water resource data in Canada were focused almost entirely on the supply side of the resource, aiming principally at defining and analyzing the physical and chemical nature of Canada's water. However, in any country, water is also indispensable to a wide range of social and economic activity, ranging from support of agriculture, fishing and recreation, to uses in manufacturing and electrical generation. A number of complex factors governing its use arise in the various broad water use sectors. Proper resource management requires extensive data on such uses. Awareness of this requirement has prompted recent federal and provincial initiatives to compile and formulate databases on the use of water resources in Canada.

In the following, most water uses which withdraw water from its source are classified as industrial and include: manufacturing, mineral extraction, agriculture and thermal power production. Municipal water use is the only withdrawal use not classed as industrial.

Industrial growth has been a crucial factor in Canada's economic development. At the time of Confederation, over 90% of Canadians were dependent upon agriculture for their livelihood, many at the subsistence level. Through the advantages offered by a rich raw material base and the inflow of foreign capital, the country has developed a diverse and productive economy. This has been due in no small measure to a bountiful supply of fresh water.

Raw materials are of vital importance in industrial development. Water is included among these raw materials, and it is the one most often taken for granted. Casual observation will indicate that all of Canada's industrial complexes are close to assured water supplies. For example, it is no coincidence that the industrial heartland of Canada lies within the Great Lakes-St. Lawrence drainage system; the system's waters serve both as a source of inexpensive power and as a medium for bulk transportation. The waters also have a number of diverse uses in the industrial processes themselves.

It is easy to see then why water can become an important factor in the locating of an industrial plant; it is by no means the only one nor the most important. Factors such as proximity to markets and raw materials often override the importance of water. As well, the possibility of recirculating water within a plant reduces the gross requirements for that plant and decreases water's role as a location factor.

Water has numerous applications in industrial operations. Its heat-absorptive capacity makes it the most common cooling medium and vast quantities are used in the cooling systems of plants. It also serves an essential role in the production of steam for generation of electricity and for industrial processes. Water often is the medium in which industrial processing takes place, such as in the electro-plating industry. Water is also incorporated in products such as soft drinks. As well, minor amounts are used for sanitation and general cleaning tasks within the plant.

Industrial water use statistics were gathered jointly by Environment Canada and Statistics Canada staff for most industries for 1972, 1976 and 1981. In Alberta, the provincial Environment Department undertook the survey. Data for various years were previously presented in various publications. Although most of the data were based upon actual surveys of water users together with estimates for non-respondents, all estimates were not equally reliable. With several surveys to draw upon, alterations to earlier data have had to be made to most categories of industrial water use. Accordingly, the data in this Year Book should be used in preference to those in earlier Canada Water Year Books.

Agricultural water use was the only industrial use not included in the 1981 industrial survey. The latest statistics given herein have been developed from an earlier survey as well as from reports from and contact with provincial and federal-provincial agencies.

Since mid-1975, municipal water use statistics have been collected in an Environment Canada database designated MUNDAT. The database was set up with the cooperation of provincial agencies and revisions are made on a continuing basis as provincial inspections are carried out.

The data arising from the 1981 survey, as well as estimates where the data were not complete, are given in Table 1. Revised data for 1976 and 1972 are given in Tables 2 and 3.

An important change herein pertains to the method of reporting water use statistics. In reporting water use on a daily basis in earlier Year Books, a misconception was introduced inasmuch as many industrial users do not operate seven days a week. Also, for irrigation and certain other uses which operate irregularly during the year, erroneous statistics result when these uses are presented in terms of daily use. To resolve this problem and to ensure comparability of data, water use data henceforth will be based on annual use and expressed in millions of cubic metres per annum. The 1981 data and revised statistics for 1972 and 1976 herein are all presented in this way.

Trends in Water Use

For the period 1972-1981, water withdrawals underwent increases both nationally and regionally, with national surveyed withdrawals growing from 24 057 million m^3 in 1972 to 37 254 million m^3 in 1981. Regionally, the major users, Ontario, Quebec and British Columbia, followed this same trend; the Prairie and Atlantic regions too began with increased withdrawals between 1972 and 1976 but withdrawals during the later period, 1976-1981, underwent a slight reduction in both regions.

As would be expected, Ontario was the major user, accounting for 45% of all withdrawals in 1972 and more than 56% in 1981. The Prairie region ranked second in withdrawals, accounting for 21% in 1972 and 14% in 1981; while this illustrates that Prairie withdrawals decreased as a portion of national withdrawals, water withdrawals on the Prairies actually increased from 5066 million m^3 in 1972 to 5342 million m^3 in 1981. The use of water as a portion of national use also decreased between 1972 and 1981 in

Table 1

Water Use in Canada – 1981

(millions of cubic metres per annum)

	Intake	Recirculation	Gross Use	Discharge	Consumption
Agriculture	3 125	–	3 125	713	2 412
Mineral Industry	648	2 792	3 440	470	178
Metallic Minerals	449	1 247	1 696	406	43
Mineral Fuels	140	1 125	1 265	17	123
Non-metallic Minerals	59	420	479	47	12
Manufacturing*	9 937	10 747	20 684	9 443	494
Food and Beverages	430	117	547	399	31
Rubber and Plastics	54	744	798	47	7
Textiles	124	51	175	119	5
Wood Products	73	57	130	69	4
Paper and Allied Products	2 899	4 612	7 511	2 740	159
Primary Metals	2 719	1 692	4 411	2 681	38
Metal Fabrication	30	130	160	29	1
Transport Equipment	109	73	182	106	3
Non-Metal Mineral Products	83	530	613	68	15
Petroleum and Coal	563	1 457	2 020	529	34
Chemicals	2 853	1 284	4 137	2 656	197
Thermal Power Generation	19 281	1 868	21 149	19 113	168
Municipal**	4 283	–	4 283	3 623	640
Utilities	2 972	–	2 972	2 526	446
Wholesale and Retail Trade	1 291	–	1 291	1 097	194
Total	37 254	15 407	52 661	33 362	3 892

* See Table 6(a) "Manufacturing Water Use" containing estimates for unsurveyed industries.
** See Table 4 "Municipal Water Use" containing estimates for rural domestic water use.

Regional Water Intake in Canada – 1981

(millions of cubic metres per annum)

	Municipal	Manufacturing	Mineral Industry	Agriculture	Thermal	Total
Atlantic Provinces	307	640	86	12	1 837	2 882
Quebec	1 369	2 319	107	82	308	4 185
Ontario	1 450	4 414	124	148	14 930	21 066
Prairie Provinces	579	382	197	2 338	1 846	5 342
British Columbia	558	2 182	134	545	360	3 779
Total	4 283	9 937	648	3 125	19 281	37 254
% of Total	11.4	26.7	1.7	8.4	51.8	100

Table 2

Water Use in Canada – 1976

(millions of cubic metres per annum)

	Intake	Recirculation	Gross Use	Discharge	Consumption
Agriculture	3 300	–	3 300	931	2 369
Mineral Industry	667	1 731	2 398	563	105
Metal Mines	542	1 421	1 963	483	59
Mineral Fuels	39	1	40	8	31
Non Metal Mines	87	306	395	72	15
Manufacturing	8 672	11 362	20 034	8 217	455
Food and Beverages	359	162	521	328	31
Rubber and Plastics	59	82	141	54	5
Textiles	139	103	242	132	7
Wood Products	331	158	489	322	9
Paper and Allied Products	3 132	5 736	8 868	2 962	170
Primary Metals	2 094	1 977	4 071	2 018	76
Metal Fabrication	8	3	11	8	–
Transportation Equipment	376	427	803	374	2
Non-Metallic Mineral Products	95	152	247	79	16
Petroleum and Coal	616	1 015	1 631	581	35
Chemicals	1 463	1 547	3 010	1 359	104
Thermal Power Generation	13 164	199	13 363	13 003	160
Municipal	3 855	–	3 855	3 322	533
Utilities	2 764	–	2 764	2 395	369
Wholesale and Retail Trade	1 091	–	1 091	927	164
Total	29 658	13 292	42 950	26 036	3 622

Regional Water Intake in Canada – 1976

(millions of cubic metres per annum)

	Municipal	Manufacturing	Mineral Industry	Agriculture	Thermal	Total
Atlantic Provinces	328	944	111	24	3 004	4 411
Quebec	1 287	1 864	223	51	433	3 858
Ontario	1 287	3 948	155	127	6 686	12 203
Prairie Provinces	485	352	103	2 579	2 385	5 904
British Columbia	468	1 564	75	519	656	3 282
Total	3 855	8 672	667	3 300	13 164	29 658
% of Total	13.0	29.2	2.3	11.1	44.4	100

Table 3

Water Use in Canada 1972

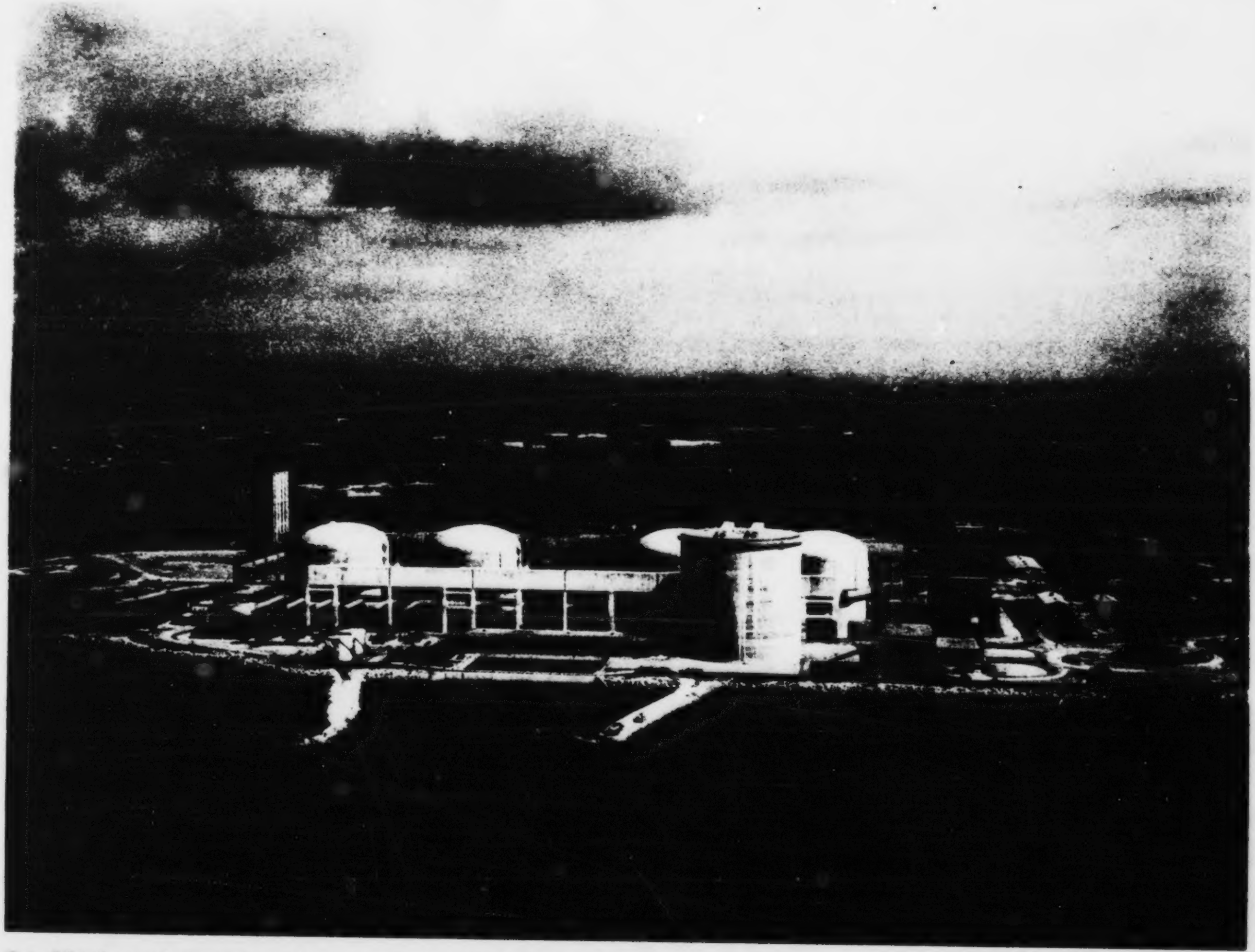
(millions of cubic metres per annum)

	Intake	Recirculation	Gross Use	Discharge	Consumption
Agriculture	2 855	–	2 855	812	2 043
Mining	362	1 791	2 153	275	87
Metal Mines	161	1 539	1 700	147	14
Mineral Fuels	42	63	105	4	38
Non-Metal Mines	159	189	348	124	35
Manufacturing	8 362	11 118	19 480	8 023	339
Food and Beverages	380	161	541	355	25
Rubber and Plastics	354	112	466	351	3
Textiles	128	47	175	123	5
Wood Products	175	44	219	170	5
Paper and Allied Products	3 094	6 595	9 689	2 982	112
Primary Metals	1 649	1 301	2 950	1 605	44
Metal Fabrication	32	38	70	30	2
Transport Equipment	192	86	278	184	8
Non-Metal Mineral Products	133	123	256	127	6
Petroleum and Coal	700	781	1 481	665	35
Chemicals	1 525	1 830	3 355	1 431	94
Thermal Generation	9 321	–	9 321	9 219	102
Municipal	3 158	–	3 157	2 684	473
Utilities	2 170	–	2 170	1 845	325
Wholesale and Retail Trade	987	–	987	839	148
Total	24 056	12 909	36 965	21 013	3 043

Regional Water Intake in Canada – 1972

(millions of cubic metres per annum)

	Municipal	Manufacturing	Mineral Industry	Agriculture	Thermal	Total
Atlantic Provinces	212	976	48	21	1 163	2 420
Quebec	1 067	1 677	59	75	414	3 312
Ontario	1 139	3 962	73	128	5 629	10 931
Prairie Provinces	372	362	134	2 160	2 058	5 086
British Columbia	347	1 385	48	471	57	2 308
Total	3 157	8 362	362	2 855	9 321	24 057
% of Total	13.1	34.8	1.5	11.9	38.7	100



Thermal power generation was responsible for the largest water withdrawals for the period under review. (Pickering Nuclear Station)

the Atlantic and Quebec regions, even though both showed an increase in use. This phenomenon was attributed to the major growth in water withdrawals for thermal generation in Ontario which overshadowed the increases in all other uses.

Trends in water use by the major users are discussed in the following:

1. Thermal Power Generation

This industrial sector (which includes both conventional and nuclear power generation plants) was responsible for the largest withdrawals in all years under review. In fact the sector increased its proportion of the national water used from 38.7% in 1972 to 51.8% in 1981. This large growth represented the combined effects of rapid growth in demand for electricity and a gradual increase in the proportion of generating capacity accounted for by nuclear power plants, which use relatively more cooling water than conventional thermal plants.

Recirculation in this sector was important only in the Prairie region (Alberta) where withdrawals of 1846 million m^3 in 1981 would have had to more than double if it had not been for recirculation (1868 million m^3 in 1981). Compared to the large water withdrawal by the sector, water consumption was relatively low owing to the fact that most plants used a once-through system of cooling, and highly consumptive cooling towers or cooling ponds were used to only a limited extent.

2. Manufacturing

Manufacturing was the second-largest water user among the sectors under study. Total water use grew from 8362 million m^3 in 1972 (34.8% of national water use) to 9937 million m^3 in 1981 (26.7% of the national total).

All of the categories – intake, recirculation, gross use, discharge and consumption – showed a general upward trend in the period 1972-1981. The main exception was recirculation which experienced a 5% downturn between 1976 and 1981. During this same period, however, intake water grew sufficiently to more than offset this downturn and to boost the gross water use above the 1976 level. It is highly likely that the manufacturing water use statistics for 1981 would have been much larger if it had not been for the economic difficulties that the world economies were experiencing.

In each of the three years, the paper and allied products subsector reported the largest water intake and it had by far the largest level of recirculation and gross use as well. The primary metals and the chemical and chemical products subsectors were the other large water users during the period under review.

Agricultural water use is a highly consumptive use, with more than 70% of the water withdrawn not being returned to source for other uses.

Ontario was the province of largest use in manufacturing during the period, followed by Quebec and British Columbia, in that order.

3. Municipal Water Use

Municipal water use underwent a general upward trend, rising from 3157 million m³ in 1972 to 4263 million m³ in 1981. Additional quantities of water made available by municipalities for industrial use and estimates of rural water use are not included in these figures but are discussed later in the section dealing with municipal water use for 1981.

With their larger populations, Ontario and Quebec accounted for the largest uses. In third position in terms of total use was the Prairie region followed by British Columbia and the Atlantic region.

4. Agriculture

The use of water by agriculture is fourth largest of the five sectors, with actual use in the three years under review ranging from a low of 2855 million m³ in 1972 to a high of 3300 million m³ in 1976. The corresponding total for 1981, at 3125 million m³, was between those two values. Thus, total withdrawal is not the significant thing about agricultural water use. What is significant is the fact that about three quarters of all withdrawals for this purpose occur in the Prairie region; furthermore, agricultural water use is a highly consumptive use, with more than 70% of the water withdrawn not being returned to source for other uses. It is not difficult to see, therefore, that this use should exert its greatest impact upon the semi-arid Prairie region and, in a sense, seriously compete with other users further downstream.

5. Mineral Industry

The mineral industry, accounting for about 2% of all water withdrawals, ranks last in terms of total intake. Its three subsectors combined used only 648 million m³ of water in 1981, a significant increase over the 1972 level of use (362 million m³) but slightly below the 1976 total of 667 million m³.

Of significance is the fact that this sector has employed recirculation to a greater extent than other sectors, with the 648 million m³ in 1981 being used and re-used more than five times to meet a gross demand of 3440 million m³.

Another significant factor is the relatively high rate of consumption attributed to the industry, ranging from 16% of intake in 1976 to 27% of intake in 1981. Of the three subsectors in 1981, mineral fuels had the highest consumptive rate (88%) while metallic minerals, which accounted for the largest intake, had the lowest consumption (10%).

WATER USE IN 1981

Municipal Water Use

Waterworks systems have had a conspicuous place in Canada's development. The first public waterwork system was constructed in 1837 in Saint John, N.B. It was followed by similar systems in Toronto (1841), Halifax (1848), and Montreal (1857). With each passing decade, the number of such systems has increased and, by 1981, 2474 Canadian communities, large and small, were served by distribution networks. Those not on such networks live in rural areas and depend upon private water sources.

Components of Municipal Water Use

Municipal water use is a consolidation of many different uses. Rarely do municipal supplies provide water solely for drinking or other household uses alone; they cater to the needs of commercial districts, small industrial establishments, and other public uses such as street cleaning, watering or public gardens and parks, public swimming pools, fountains and firefighting. Excluding industrial demand, the municipal water uses can be classified into three main subgroups: residential, commercial and public (including institutions). A fourth category, other, includes amounts lost and unaccounted for. The breakdown by user group is:

Residential	63%
Commerical	14%
Public	5%
Other	18%

Residential water use includes several indoor and outdoor uses. The indoor uses and the percentage each consumed are:

Bathing and personal	28%
Laundry and dishes	23%
Toilet	45%
Drinking and Cooking	4%

Indoor water use has a daily cycle which exhibits morning and evening peaks; this daily cycle is stable throughout the year. Seasonal peaking and extremes in daily peaking are caused by uses which occur outside the home, principally lawn sprinkling.

Lawn sprinkling is required only when rainfall is light. Since it occurs only during the summer months, lawn sprinkling is responsible for the seasonal peaking of residential water use. This use is also responsible for high daily residential water use during the summer months. As water supply system design is determined by maximum daily water use, lawn sprinkling has a significant influence on the design capacity, and hence the cost, of municipal water supply systems.

While the statistics presented herein reflect municipal use as defined above, they do not include all of the water made available by municipal systems. Water supplied to industry from urban systems, where clearly identified, has been separated from the municipal uses and has been reported in the industrial sector. In 1981, water intake for municipal purposes in Canada rose to 4263 million m³ (Table 4) while another 811 million m³ was supplied by municipal plants for industrial uses, indicating that municipal plants provided a total of 5074 million m³ in 1981. A further 347 million m³ was estimated to have been required by rural users for domestic water use in 1981. Estimates of rural domestic use in earlier years include 307 million m³ in 1976 and 294 million m³ in 1972. Of the 811 million m³ provided to industry in 1981, Manufacturing received 683 million m³, the Mineral Industry – 52 million m³, and Thermal Power Generation – 76 million m³. Agriculture used a small amount of water from municipal systems but the amount of such use is not known.

Table 4

Municipal Water Use – 1981

(millions of cubic metres per annum)

	Utilities	Wholesale and Retail Trade
Newfoundland	50	99
Prince Edward Island	4	
Nova Scotia	60	
New Brunswick	94	
Quebec	931	438
Ontario	992	458
Manitoba	86	150
Saskatchewan	72	
Alberta	271	
British Columbia	412	146
Total	2 972	1 291

A further 811 million m³ of water was made available by municipal systems for industrial uses.

Not included above are statistics on rural domestic water use estimated to total 347 million m³ in 1981, with regional distribution Atlantic Provinces 60 million m³, Quebec 82 million m³, Ontario 99 million m³, Prairie Provinces 70 million m³, and British Columbia 36 million m³.

Source: Derived by Inland Waters Directorate using MUNDAT data.

Factors Affecting Municipal Water Use

Many factors have been demonstrated to influence water use in a municipality but it is difficult, if not impossible, to isolate the effects of each. Rather, it is the combined influence of the many factors which alter water use patterns.

Community size is the most obvious factor influencing water use since, as population increases, residential, commercial and industrial water uses in that municipality also will grow in number and diversity.

Cost is also a factor influencing water use. Researchers have found that as the cost of water to a user increases, less water is used. On the other hand, water demand is also related to the income of the individual user. As income increases, so also does water use, although at a lower rate.

Seasonality also affects municipal water use. In both large and small communities, the summer season is accompanied by higher water uses, with the peak months generally being June through August. Most of this higher use can be attributed to the residential sector, which suggests that outdoor water uses are major factors contributing to the higher summer water withdrawals. Part of this can be attributed to lawn and garden watering during extended dry periods.

Losses in a municipal water system also can often contribute to large water uses. Comparing the data on water pumped from a municipal water treatment plant with the metered use later in the system will invariably show an amount unaccounted for. This may be due in part to public water connections for public buildings, parkland watering, street flushing or fire fighting, none of which are metered. However, estimates suggest that such water use should not exceed about 5% of the yearly pumpage; where the losses exceed this level, they are generally attributed to water main leaks and breaks, or inaccurate metering devices. For Canada as a whole, some 18% of municipal water use is unaccounted for.

Community size is the most obvious factor influencing municipal water use since, as population increases, residential, commercial and industrial water uses in that municipality also will grow in number and diversity.

Municipal Water Charges

Researchers have demonstrated that less water is used as the cost of water to the user increases. Nevertheless, virtually no efforts are being made in Canada to use water pricing as an incentive for rational, efficient resource use. Instead, water rates and charges in all sectors of the economy are related to little more than token charges to provide revenue offsetting contruction and operating charges. Construction of water supply and treatment systems already comprises one of the most costly items of public expense, and will be even more costly in the future because of competing demands for capital. It therefore becomes desirable from a policy standpoint to attempt to limit water supply expenditures by curtailing demands. One method of doing so is through the use of economically-based pricing systems.

A survey of Canadian municipalities was undertaken late in 1983 to determine municipal water charges. In almost all cases, the residential rate structure has either been a flat rate, or a declining rate as more water is used. Only a few municipalities employed an increasing rate as more water was used.

To obtain a base of comparison of costs for the survey, the average household water use was selected at an arbitrary 20 000 litres per month. On that basis, the average monthly household charge ranged from $1.77 to $25.00, depending upon the municipality. For the twelve largest municipalities (with populations of 100 000 or greater) the range was $1.77-$16.89, with a median value just under $7.00.

Urban Infrastructure – Funding Inadequacies

Public works facilities such as sewer, water, street systems, bridges, parks and community centres are collectively referred to as urban infrastructure. These facilities are important to the functioning of urban areas and some forms – sewers, water, roads and bridges – are essential to the very existence of urban areas.

Over the last few decades, Canada has undergone rapid urbanization, necessitating a significant expansion in urban infrastructure. Until the 1970s, the maintenance of these facilities remained at an acceptable level because economic conditions were good, and many facilities were relatively new. Subsequently, increasing resistance to rising taxes and a growing array of new services designed to improve the quality of life has added to the problem.

High interest rates in recent years have resulted in a growing reluctance to borrow money for these services. In addition, growing environmental concerns and increasing public involvement have made reconstruction more difficult and more expensive. Compounding the problem is the recent recession accompanied by high unemployment.

A combination of these factors and others has resulted in the deferral of necessary work on infrastructure and a growing backlog of maintenance and replacement work. If this is permitted to grow, a point will be reached where unreasonably high financing will be required to bring the infrastructure to acceptable levels.

Studies of municipal water supply infrastructure for 1) the Inland Waters Directorate and 2) the Federation of Canadian Municipalities were reported upon in 1984 for the Atlantic Provinces (March) and nationally (June). The latter study offered seventeen conclusions and recommendations to halt the trend discussed above. A second phase to the national study has been recommended which, if approved, will analyse the problem in greater detail, outline specific policies for dealing with the problem, move to correct deficiencies in the infrastructure, and provide the basis for cooperation between the three levels of government in solving the problem.

Over the last few decades, Canada has undergone rapid urbanization, necessitating a significant expansion in water and sewer facilities.

Water Use in the Manufacturing Industry

Of the many sectors of water use in Canada, manufacturing is the most complex because it includes many subsectors. To illustrate, in 1972, a total of 18 manufacturing subsectors were surveyed for water use. However, eleven subsectors in manufacturing accounted for between 97% and 98% of the sectoral water intake in that year. As a result, subsequent surveys have concentrated on these eleven subsectors.

Table 5 shows the eleven subsectors together with the total number of plants and employees in each. Statistics on six other subsectors which were not surveyed are included in Table 5. The Food and Beverage Industries are seen to have the largest number of both plants (1513) and employees (167 925). Plants manufacturing Transportation Equipment had the second-largest number of employees (149 876). Non-Metallic Minerals, and Chemicals, were second and third largest in number of plants with 674 and 572 respectively.

Water Use

The use of water by the Manufacturing Sector in 1981 is detailed in Tables 6 and 6(a). In Table 6, manufacturing industries that were surveyed are shown to have accounted for a total of 9937 million m^3 of water for all purposes. This amount was extended to meet a gross use of 20 684 million m^3 in 1981, indicating that the original intake was reused slightly more than twice through recirculation. Water consumption totalled 494 million m^3, or 5% of total intake; the remaining 9442 million m^3 was discharged back to the environment.

Water use statistics for manufacturing industries that were not surveyed have been estimated and listed in Table 6(a). They were derived using water use coefficients from U.S. sources and Canadian employment data. Therefore, to obtain total water use by manufacturers in Canada, the totals in Table 6(a) must be added to those of Table 6. On the basis of intake, the estimated values represent about 2.6% of the total for all manufacturers. Because little is known about the water uses in Table 6(a), however, they have been segregated from the surveyed industries in Table 6 and disregarded completely in subsequent tables.

Three industries – Paper and Allied Products, Primary Metals, and Chemical Products – were the main water users in the manufacturing sector in 1981, and together they accounted for 85% of total intake and 80% of total consumption. Their individual intakes fell within a narrow band between 2899 million m^3 (Paper and Allied Products with the largest intake) and 2719 million m^3 (Primary Metals). The Chemical Products Industry used 2853 million m^3 during 1981. Paper and Allied Products also reported the largest gross use.

On a provincial basis, the manufacturing industry in Ontario reported the largest water use followed by Quebec and British Columbia in that order. Together, the three provinces accounted for 90% of all water intake and 87% of gross use.

Table 5

Employee and Plant Statistics for the Manufacturing Sector – 1981

Surveyed Industries	Number of Employees	Number of Plants
Food and Beverages	167 925	1 513
Rubber and Plastics	46 060	450
Textiles	33 792	162
Wood Products	43 594	360
Paper and Allied Products	96 331	271
Primary Metals	111 972	171
Metal Fabricating	30 136	324
Transportation Equipment	149 876	329
Non-Metallic Minerals	39 270	674
Petroleum and Coal	11 790	42
Chemical Products	64 424	572
Total (surveyed)	**795 170**	**4 868**
Industries not Surveyed		
Tobacco	8 362	–
Furniture	50 900	–
Leather	24 922	–
Machinery	108 444	–
Electrical	122 557	–
Miscellaneous	66 891	–
Total (unsurveyed)	**382 076**	–

Table 6

Water Use in the Manufacturing Industry (Surveyed) – 1981

(millions of cubic metres per annum)

Industrial Sector	Intake	Recirculation	Gross Use	Discharge	Consumption
Food and Beverages	430	117	547	399	31
Rubber and Plastics	54	744	798	47	7
Textiles	124	51	175	119	5
Wood Products	73	57	130	69	4
Paper and Allied Products	2 899	4 612	7 511	2 740	159
Primary Metals	2 719	1 692	4 411	2 681	38
Metal Fabricating	30	130	160	29	1
Transportation Equipment	109	73	182	106	3
Non-Metallic Minerals	83	530	613	68	15
Petroleum and Coal	563	1 457	2 020	529	34
Chemical Products	2 853	1 284	4 137	2 656	197
Total (surveyed)	**9 937**	**10 747**	**20 684**	**9 443**	**494**
Province					
Newfoundland	93	13	106	92	1
Prince Edward Island	4	–	4	3	1
Nova Scotia	270	96	366	255	15
New Brunswick	273	285	558	257	16
Quebec	2 319	2 740	5 059	2 188	131
Ontario	4 414	3 633	8 047	4 222	192
Manitoba	95	179	274	90	5
Saskatchewan	43	182	225	40	3
Alberta	243	929	1 173	179	64
British Columbia	2 182	2 690	4 872	2 116	66
Yukon and NWT	1	–	1	1	–
Total (surveyed)	**9 937**	**10 747**	**20 684**	**9 443**	**494**

Source: 1981 Water Use Survey

Table 6(a)

Estimates of Water Use in Unsurveyed Manufacturing Industries – 1981

(millions of cubic metres per annum)

	Intake	Recirculation	Gross Use	Discharge	Consumption
Tobacco	4	29	33	3	1
Furniture	27	1	28	27	–
Leather	9	1	10	8	1
Machinery	67	95	162	64	3
Electrical	129	346	475	124	5
Miscellaneous	28	39	67	25	3
Total (unsurveyed)	**263**	**512**	**775**	**250**	**13**
Total (surveyed and unsurveyed)	**10 200**	**11 259**	**21 460**	**9 693**	**507**

Source: Inland Waters Directorate internal study.

Recirculation and Consumption Rate

The recirculation rate shown in Table 7 is formed by the ratio of the actual amount of recirculation and water intake. It is a measure of the amount of additional water that would be required if recirculation was not feasible. The minimum value of the rate is 0% where gross use and water intake are equal and denotes no recirculation. The ratio attains high values for industries which recirculate large amounts of water. The Rubber and Plastics Industry is shown to have the highest recirculation rate (1378%) whereas the Food and Beverages Industry had the lowest (27%). Of the three industries with major intakes, only the Paper and Allied Products rate (159%) was above the national average; the other two, Primary Metals and Chemical Products, had rates of 62% and 45% respectively.

The consumption rate, also shown in Table 7, is an index of the amount of water lost during production, most commonly through evaporation or incorporation within the product. On average, the consumption rate was 5% but varied between 1.4% for Primary Metals and 18.1% for Non-Metallic Products.

Table 7 also reveals provincial recirculation and consumption rates. In general the Atlantic Provinces employed a low level of recirculation; Ontario's rate of recirculation was relatively low owing to an abundance of water from the Great Lakes. The corresponding rates in the three Prairie Provinces were substantially higher than those in the rest of Canada, reflecting the need for greater recirculation in a generally semi-arid climate. British Columbia's rate of recirculation was not as high as that for the prairies but, nevertheless, it was above average, as was Quebec's.

Provincial consumption rates ranging up to 7% were relatively uniform in most of Canada. The exception was Alberta which had a consumption rate of 26.6%.

Table 7

Water Recirculation and Consumption Rates in the Manufacturing Industry – 1981

Industrial Sector	**Recirculation Rate (%)**	**Consumption Rate (%)**
Food and Beverages	27	7.1
Rubber and Plastics	1 378	13.5
Textiles	41	4.2
Wood Products	78	5.9
Paper and Allied Products	159	5.5
Primary Metals	62	1.4
Metal Fabricating	433	3.3
Transportation Equipment	67	2.7
Non-Metallic Minerals	638	18.1
Petroleum and Coal	259	6.1
Chemical Products	45	6.9
Average	**108**	**5.0**
Province		
Newfoundland	14	1.2
Prince Edward Island	–	–
Nova Scotia	36	5.6
New Brunswick	104	5.9
Quebec	118	5.7
Ontario	82	4.4
Manitoba	188	5.3
Saskatchewan	423	7.0
Alberta	382	26.6
British Columbia	123	3.0
Average	**108**	**5.0**

Source of Supply

Table 8 indicates the sources of water intake for manufacturing. The table reveals that 97% of the water was derived from freshwater sources; the remainder was brackish water obtained mainly from tidal areas.

Most of the freshwater was self-supplied, with public water supply providing only 7% of manufacturing's total intake. Fresh surface water provided 89% of manufacturing's intake.

The Food and Beverage Industry was the largest user of the public water supply, obtaining 42% of its intake from this source. This is because the industry is composed of many relatively small water users who have a requirement for high quality water but who find it uneconomic to provide their own supply. In contrast, the three largest users – Paper and Allied Products, Chemical Products, and Primary Metals – consist of fewer and generally larger plants, and provide almost all of their own water supplies.

The table reveals that manufacturing industries in the Atlantic Provinces were the main users of brackish water, getting 29% of their intake from that source. They were also major users of public supply for 18% of their water intake compared to an average of 7% nationally. As a result, industries in the Atlantic Provinces derived only 53% of their intake from self-supplied freshwater sources compared to 90% for the national average and 94% for Ontario and British Columbia. Nova Scotia was the principal user of brackish water, with 50% of its supply coming from that source.

The Prairie Provinces were more dependent than other provinces on self-supplied ground water sources, with about 5% of their total intake being ground water; the national average was about 1%.

Table 8

Source of Intake Water in the Manufacturing Industry – 1981

(millions of cubic metres per annum)

	Freshwater				Brackish Water			
	Public Supply	Self-Supplied			Self-Supplied			
		Surface	Groundwater	Other	Ground	Tide	Other	Total
Food and Beverages	179	172	31	1	–	46	–	429
Rubber and Plastics	32	13	8	–	–	–	–	54
Textiles	28	94	2	–	–	–	–	124
Wood Products	14	27	1	–	–	30	–	72
Paper and Allied Products	116	2 742	28	7	–	8	–	2 900
Primary Metals	85	2 536	2	10	–	84	1	2 718
Metal Fabricating	21	8	1	–	–	–	–	30
Transportation Equipment	49	59	–	–	–	–	–	108
Non-Metallic Minerals	22	49	5	6	–	–	–	82
Petroleum and Coal	20	489	2	–	–	50	2	563
Chemical Products	119	2 675	11	9	1	39	–	2 854
Total	**684**	**8 864**	**91**	**33**	**1**	**258**	**3**	**9 934**
Province								
Newfoundland	17	53	–	–	–	23	–	93
Prince Edward Island	2	1	1	–	–	1	–	5
Nova Scotia	47	80	4	3	–	135	1	270
New Brunswick	51	193	3	–	–	24	1	272
Quebec	206	2 080	16	15	–	2	–	2 319
Ontario	266	4 111	21	13	1	–	1	4 413
Manitoba	10	74	11	–	–	–	–	95
Saskatchewan	6	35	2	–	–	–	–	43
Alberta	24	211	6	1	–	–	–	242
British Columbia	55	2 026	27	1	–	73	–	2 182
Totals	**684**	**8 864**	**91**	**33**	**1**	**258**	**3**	**9 934**
% of Total Intake	7	89	1	–	–	3	–	100

Purpose of Water Use

The breakdown of total intake by initial use of water is shown in Table 9. Cooling, condensing and steam was the main use of new water taken into manufacturing plants in 1981, accounting for 63% of total intake. Processing accounted for about 34.5% of intake, with sanitary and other uses accounting for 2% and 0.5% respectively. Cooling, condensing and steam was the main initial use in nine of the eleven industries surveyed.

As already indicated, Paper and Allied Products was the principal water user in 1981 (2899 m³), although Chemical Products and Primary Metals were of a similar magnitude with 2853 m³ and 2719 m³ respectively. The Paper and Allied Products Industry used most of its water intake for processing. In contrast, both Chemical Products and Primary Metals reported the largest water uses for cooling, condensing and steam. Sanitary use, while relatively low in all industries, was largest in the employee intensive industries – Primary Metals, Paper and Allied Products, Food and Beverages and Chemical Products.

On a provincial basis, Ontario was the largest water user in most categories. British Columbia and Quebec were also major users mainly for cooling, condensing and steam but also for processing.

Table 9

Purpose of Water Use in the Manufacturing Industry – 1981

(In millions of cubic metres per annum)

Industrial Sector	Processing	Cooling, Condensing and Steam	Sanitary	Other	Total
Food and Beverages	129	259	36	5	429
Rubber and Plastics	19	32	3	–	54
Textiles	45	76	2	–	123
Wood Products	20	47	5	–	72
Paper and Allied Products	2 188	658	43	10	2 899
Primary Metals	711	1 943	54	11	2 719
Metal Fabricating	16	12	2	–	30
Transportation Equipment	48	52	6	2	109
Non-Metallic Minerals	19	58	3	2	82
Petroleum and Coal	38	516	4	6	564
Chemical Products	195	2 614	31	13	2 853
Total	**3 428**	**6 267**	**189**	**49**	**9 933**
Province					
Newfoundland	69	23	2	–	93
Prince Edward Island	2	1	–	–	3
Nova Scotia	114	147	6	3	270
New Brunswick	185	71	9	7	272
Quebec	867	1 383	64	5	2 319
Ontario	1 272	3 062	53	26	4 413
Manitoba	70	21	3	1	95
Saskatchewan	26	16	1	–	43
Alberta	90	144	4	4	242
British Columbia	733	1 400	47	3	2 183
Total	**3 428**	**6 267**	**189**	**49**	**9 933**
% of Total	34.5	63	2	0.5	100

Treatment of Intake Water in Manufacturing

Table 10 shows both the nature of treatment and quantity of intake water treated. In general, it is clear that manufacturing industries treated substantial amounts of intake water prior to use. Overall, 58% of all intake water was screened while 34% was chlorinated and disinfected. Lesser amounts were filtered or treated for corrosion, slime, hardness or alkalinity.

The three main users – Paper and Allied Products, Primary Metals and Chemical Products – dominated the manufacturing scene and accounted for most of the intake water treated.

Paper and Allied Products had by far the greatest need for filtration. Chemical Products was foremost in screening, and both Primary Metals and Chemical Products had about equal need for chlorination and disinfection.

Since some plants employ more than one treatment process, the summation of the various amounts treated for some industries will be greater than their total intakes. On the other hand, a substantial number reported no treatment.

Table 10

Treatment of Intake Water in the Manufacturing Industry – 1981

(millions of cubic metres per annum)

	Intake	Screening	Chlorination, Disinfection	Filtration	Corrosion, Slime Control	Hardness, Alkalinity Control	Other
Food and Beverages	430	43	107	48	16	22	6
Rubber and Plastics	54	6	3	1	1	4	–
Textiles	124	57	38	22	7	15	1
Wood Products	73	29	1	4	–	2	–
Paper and Allied Products	2 899	1 374	871	1 027	151	209	131
Primary Metals	2 719	1 713	1 121	144	672	24	288
Metal Fabricating	30	1	–	3	–	1	–
Transportation Equipment	109	52	5	–	1	2	–
Non-Metallic Minerals	83	28	8	1	–	1	–
Petroleum and Coal	563	458	155	25	120	36	38
Chemical Products	2 853	2 008	1 065	143	63	86	28
Total	**9 937**	**5 769**	**3 374**	**1 418**	**1 031**	**402**	**492**
% of Total Intake Water	100	58	34	14	10	4	5

Water Discharge

Table 11 reveals where industries dispose of their water after use. Freshwater bodies are the main disposal areas for almost 72% of the waste water, another 22% is discharged to tidewater, and only 5% goes directly to public sewers. The remainder, less than 1%, either is discharged to ground water or is transferred to other uses.

The Food and Beverage Industry discharged 157 million m³ (or 39%) of its waste water to public sewers in 1981, the largest of all in manufacturing. In contrast the major water users used public sewers for only 1% to 3% of discharges. This can be attributed in part to the fact that the Food and Beverage Industry usually does not have sufficient water discharge to justify building and operating individual waste treatment facilities. Also, their wastes, being composed mainly of biochemical oxygen demand and suspended solids, tend to be compatible with municipal waste treatment processes. On the other hand, the larger volumes of other industries, and the fact that some of their pollutants are incompatible with municipal treatment processes, necessitate that they be handled by the water users themselves.

Table 11

Point of Wastewater Discharge in the Manufacturing Industry – 1981

	Discharge	Freshwater Body	Tidewater	Public Sewer	Ground	Transferred to Other uses
Food and Beverages	399	167	66	157	8	1
Rubber and Plastics	47	17	–	30	–	–
Textiles	119	89	–	30	–	–
Wood Products	69	34	30	3	1	–
Paper and Allied Products	2 740	1 885	813	28	13	1
Primary Metals	2 681	1 472	1 092	87	12	18
Metal Fabricating	29	2	–	25	2	–
Transportation Equipment	106	77	3	26	–	–
Non-Metallic Minerals	68	52	–	13	3	–
Petroleum and Coal	529	466	57	5	1	–
Chemical Products	2 656	2 509	64	75	6	2
Total	9 443	6 770	2 125	479	46	22
% of Discharge	100	72	22.5	5	0.5	–

Treatment of Discharge Water

Many of the firms surveyed undertook some treatment of their waste waters prior to discharge. The quantities of such waters are shown in Table 12, by type of treatment. The table indicates that 3520 million m³ or 37% of all water discharged by manufacturing firms in 1981 underwent primary treatment, that is, it received mechanical methods of treating wastes, such as screening, settling, coagulation and filtration. Only 7% of the discharge water received secondary treatment, that is, some form of biological treatment to reduce the biochemical oxygen demand of the effluent. Tertiary treatment offering specialized removal, for example, phosphorus, was applied to less than 1% of the waste water.

The table shows that Paper and Allied Products had the largest amounts of water treated in all three categories; the 1254 million m³ treated at primary level was 46% of all water discharged by this industry, and almost 36% of the water treated at primary level by all manufacturing firms. The table also reveals that the Petroleum and Coal Industry treated the largest proportion of its waste water; although they ranked fourth in the amount of water discharged, petroleum and coal firms treated 83% of their discharge water at the primary treatment level, followed by lesser amounts at secondary and tertiary levels.

Table 12

Treatment of Discharge Water in the Manufacturing Industry – 1981

(millions of cubic metres per annum)

	Total Discharge	Primary	Secondary	Tertiary
Food and Beverages	399	78	20	3
Rubber and Plastics	47	5	–	–
Textiles	119	12	7	–
Wood Products	69	5	1	–
Paper and Allied Products	2 740	1 254	551	16
Primary Metals	2 681	659	3	4
Metal Fabricating	29	10	2	1
Transportation Equipment	106	34	4	–
Non-Metallic Minerals	68	8	1	–
Petroleum and Coal	529	437	62	7
Chemical Products	2 656	1 020	47	4
Total	9 443	3 520	698	35
% of Total Discharge	100	37	7	0.4

Water Cost

To overcome a deficiency in water-related expenditures for the manufacturing sector, the 1981 survey expanded upon the 1976 questionnaires and requested data on a wide range of costs. These are shown in Table 13. These costs are mainly annual operation and maintenance costs but, in the case of acquisition cost, also include the purchase price of water from municipal water supply systems.

Because it buys most of the water that it uses, the Food and Beverage Industry has the highest acquisition cost, reflecting the value added to the treated water compared to other industries that provide their own supply from untreated sources. However, when other intake water costs are considered, the Total Intake Cost to the Food and Beverage Industry ranks third highest, behind both Paper and Allied Products and Chemical Products and thus is not as disproportionate as suggested in the acquisition costs column. The survey results do not distinguish between purchased costs and operation and maintenance costs.

If one looks at the combined Intake and Discharge water costs, it becomes apparent that Paper and Allied Products had the highest total costs in 1981 ($109.6 million) followed by the Chemical Products Industry ($80.5 million) and the Food and Beverages Industry ($43.0 million). Annual costs for all industries totalled about $350 million.

Table 13

Water Costs in the Manufacturing Industry – 1981

(millions of dollars)

Industrial Group	Intake				Discharge	
	Acquisition	Treatment	Recirculation	Total	Treatment	Total
Food and Beverages	27.0	6.0	3.5	36.5	6.5	43.0
Rubber and Plastics	3.7	1.1	2.0	6.8	0.7	7.5
Textiles	3.8	1.6	0.4	5.8	0.6	6.4
Wood Products	1.8	0.4	0.4	2.6	0.4	3.0
Paper and Allied Products	14.6	35.2	7.3	57.1	52.5	109.6
Primary Metals	16.2	9.2	4.0	29.4	11.7	41.1
Metal Fabricating	2.9	0.3	0.9	4.1	1.9	6.0
Transportation Equipment	8.1	1.2	1.5	10.8	7.3	18.1
Non-Metallic Minerals	4.8	0.9	1.5	7.2	0.4	7.6
Petroleum and Coal	4.9	6.1	5.6	16.6	11.6	28.2
Chemical Products	21.2	24.0	19.4	64.6	15.9	80.5
Total	**109.0**	**86.0**	**46.5**	**241.5**	**109.5**	**351.0**
Indicated cost per m^3 (cents)	1.1	0.9	0.4		1.2	

Water Use in Canada's Mineral Industry

Canada leads the world in value of mineral exports and ranks third among the diversified mineral producers in non-fuel mineral production behind the United States and the Soviet Union. The mineral industry has been a major factor in Canada's economic development and is still the main force in the northward advance of Canada's frontiers of population and economic activity.

Canada produces 60 different minerals from domestic deposits. In terms of volume, some of the more important minerals produced are copper, nickel, lead, zinc, iron ore, coal, potash, asbestos and precious metals. The most valuable product of Canada's mineral industry, however, is crude petroleum.

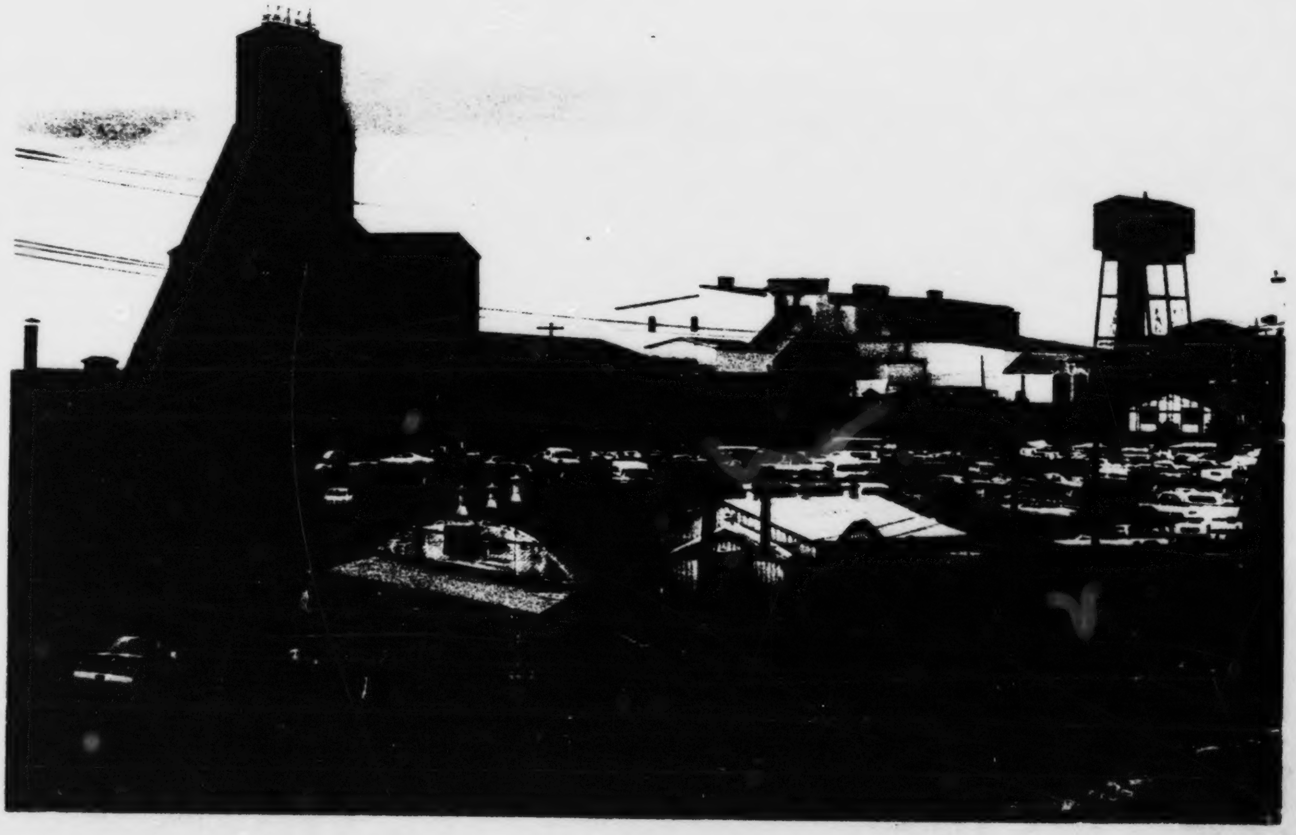
The prices of metals were somewhat reduced in 1981 by the relatively depressed state of the industrial economies; this was offset, however, by the value to Canada of mineral fuels which continued to rise in 1981. Statistics Canada reported the value of production in the mining industries in 1981 was $29.1 billion, a small increase over 1980.

Canada produces most minerals needed for modern economies although a few such as manganese, chromium, bauxite and tin, must be imported.

The location of mineral extraction activities is normally some distance from major urban areas, but there are many large communities which have grown up adjacent to a mine, with mining being the raison d'être for that community's existence.

As a rule, mineral extraction activities in Canada are seldom far from an ample water supply; in fact, many mines require constant pumping to prevent inundation of their underground workings.

The mineral industry has been a major factor in Canada's economic development.



Types of Water Use

As in manufacturing, principal water uses in mining and milling are for processing and cooling purposes. In the mining operation, that is, the actual extraction of the mineral from the ground, water is used at the ore face for mucking and slushing operations. Water is also used for dust control, to cool drills and for excavating equipment.

The milling operation is the first step in processing the raw ore. Milling consists of breaking down the raw ore into a form suitable for recovery of the minerals. Crushing is the mechanical breaking down of the ore segments into pebble-sized pieces. The pieces then may be subjected to one or more grinding processes in ball mills, during which time water is introduced to the ore to form a slurry from which the desired minerals or elements are recovered in subsequent processes. The main function of the milling operation is to concentrate the ore into as pure a form as possible before transportation to the smelter or refinery for further processing. One common concentration method is flotation, with water being the medium in which the process occurs. Water is also used for washing the ore at various stages in the production process and for carrying away the mill tailings or waste.

In petroleum extraction, most of the water is used for deep well injection in order to maintain sufficient pressure to force the crude oil to the surface. The water injected in such a process obviously cannot be recirculated, and is considered as being consumed.

The amount of water used in mineral extraction and related activities is dependent upon the type of circulation system in use at the individual mine site. There are three principal types of circulation systems – the once-through system, the tailings pond plus decant system, and the tailings pond plus recirculation system. The once-through system is the one that requires the most water. Tailings ponds are shallow basins into which mill solids (tailings) and liquid wastes are discarded; these ponds are often dammed to prevent the direct flow of wastewater to surface streams. They serve in part as waste treatment systems in that the solid particles contained in the wastewater are allowed to settle out and remain in the pond. When used with the

One use of water in mining is at the ore face for mucking and slushing operations.

decant, or overflow system, the wastewater is impounded and excess volumes of water are allowed to flow over the tailings dam into surface streams. The tailings and decant system does not reduce the amount of water used as compared to the once-through system, although it can lead to a significant increase in water consumption at the mine site due to evaporation from the pond. The tailings plus recirculation system recycles the wastewater back to the milling operation. At some operations, wastewater treatment is required prior to recycling. This type of circulation system is used in drier areas of the country to conserve water and to provide pollution control. Some operations using this system recycle most of their wastewater, thereby significantly reducing their water intake; others may recycle lesser amounts depending on site specific factors.

Metal mining, clearly the largest water user in the mineral industry, is distributed widely in Canada, generally in the more lightly settled portions of the country. Fuel extraction, on the other hand, is centred in the coal, oil and gas fields of Alberta, British Columbia and Saskatchewan; water is mainly used in the oil and gas fields to maintain adequate well pressure to enable pumping and in the process extracting oil from oil sands. In the coal industry, it is used in the coal cleaning processes and for dust control.

Tailing ponds serve in part as waste treatment systems in that the heavier particles contained in the wastewater are allowed to settle out in the pond.

Water Use Statistics

Table 14 displays water use data for the three sectors in the mineral industry. It shows that metal mines make the greatest demands on the water, with copper-gold-silver mines accounting for 150 million m^3 per annum or 23%, and iron mines, for 122 million m^3 per annum (19%). Oil and natural gas (mineral fuels) had the next largest intake with 121 million m^3 per annum (almost 19%).

Oil and natural gas production reported the largest gross use (1171 million m^3 per annum), followed by iron mines (969 million m^3 per annum). In the non-metal mines, potash mines made relatively small demands on intake water (only 14 million m^3 per annum) but this amount was recirculated almost 30 times to produce a gross use of 417 million m^3 per annum.

The discharges (normally the amounts of intake water remaining after use) are seen to be greater than the intake for most subsectors. This is attributed to ground water seepage which was pumped as part of discharge. In particular, gold mines, with an intake of 67 million m^3 per annum and a discharge of 800 million m^3 per annum, are seen to have significant levels of ground water seepage. A change in the questionnaire to respondents asked for total discharge but did not request that intake and ground water seepage be shown separately. Accordingly, Table 15 has been prepared showing estimates of these two amounts as well as estimates of water consumption in the mineral industry on the basis of data for earlier years.

As shown in Table 15, more than one quarter of the water withdrawn by the mineral industry is considered to be lost or consumed. This is primarily due to water use in

Table 14

Water Use in the Mineral Industry by Mineral Category – 1981

(millions of cubic metres per annum)

	Intake	Recirculation	Gross Use	Discharge*
Metal Mines	449	1 247	1 696	1 240
Copper-Gold-Silver	150	307	457	166
Iron	122	847	969	126
Gold	67	11	78	800
Silver-Lead-Zinc	59	17	76	90
Nickel-Copper	19	34	53	23
Uranium	22	16	38	24
Molybdenum	5	8	13	7
Silver-Cobalt	1	–	1	1
Miscellaneous	4	7	11	3
Mineral Fuels	140	1 125	1 265	108
Oil and Natural Gas	121	1 050	1 171	73
Coal	19	75	94	35
Non-Metal Mines	59	420	479	80
Salt	33	3	36	30
Potash	14	403	417	15
Asbestos	4	3	7	23
Feldspar and Quartz	3	1	4	3
Gypsum	1	1	2	8
Soapstone and Talc	–	–	–	–
Miscellaneous	4	9	13	1
Total	648	2 792	3 440	1 428

* The discharge is often greater than intake because of ground water seepage.

the mineral fuels sector which was estimated to have consumed about 88% of the water withdrawn for that sector.

Table 15 reveals that metal mines experienced most of the ground water seepage, with relatively significant amounts in the mineral fuels sector as well. In terms of consumption, however, metal mines had the lowest rate (less than 10% of intake) while mineral fuels had the largest (88%). The average consumption for all mining categories was 27%.

Table 16 reports on the provincial breakdown of water use in the mineral industry. Four provinces – Alberta, Ontario, British Columbia and Quebec – were the largest users, accounting for 76% of all water use in the mineral industry. Recirculation of water made gross use highest in Alberta and Newfoundland. Quebec had by far the highest discharge, suggesting that the mines with significant ground water seepage were

Table 15

Estimates of Water Consumption in the Mineral Industry – 1981

(millions of cubic metres per annum)

	Intake	Discharge	Source of Discharge: Ground Water Seepage	Source of Discharge: Intake	Consumption
Metal Mines	449	1 240	834e	406e	43
Mineral Fuels	140	108	91e	17e	123
Non-Metal Mines	59	80	33e	47e	12
Total	**648**	**1 428**	**958e**	**470e**	**178**

e – estimated

Table 16

Water Use in the Mineral Industry by Province – 1981

(millions of cubic metres per annum)

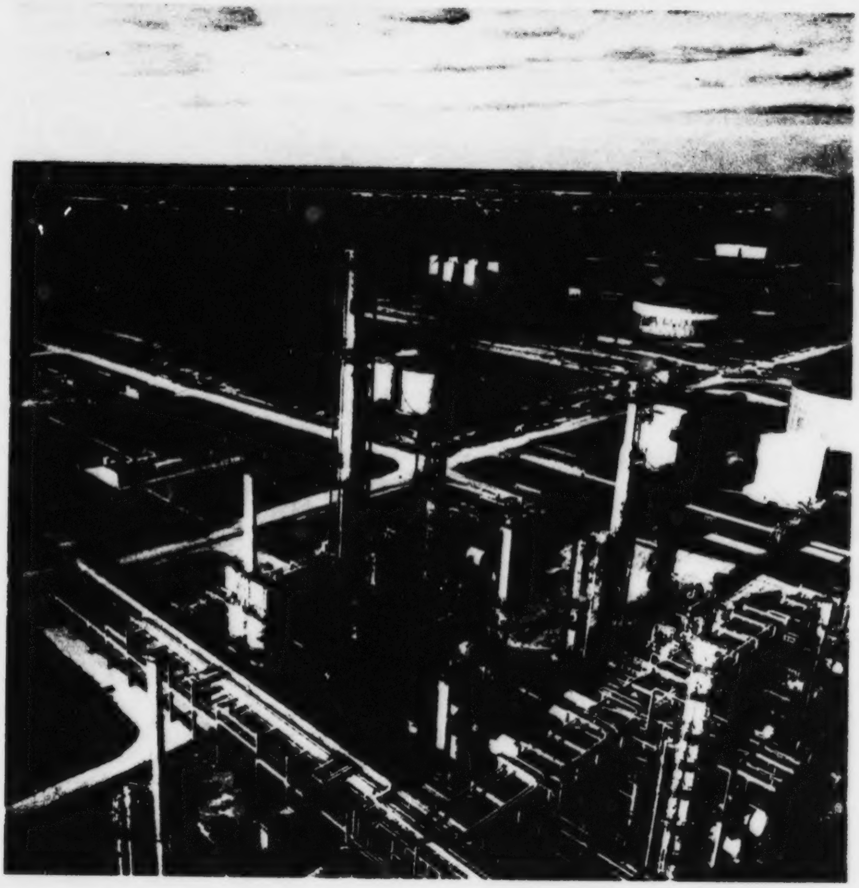
Province	Intake	Recirculated	Gross Use	Discharge*
Newfoundland	58	552	611	73
Nova Scotia	12	5	17	23
New Brunswick	15	5	20	23
Quebec	107	226	333	893
Ontario	124	164	288	125
Manitoba	13	9	21	13
Saskatchewan	31	416	447	29
Alberta	139	1 054	1 193	90
British Columbia	124	350	474	139
Yukon	10	4	14	11
Northwest Territories	15	7	22	9
Total	**648**	**2 792**	**3 440**	**1 428**

See Table 15 for estimates of water consumption in the mining industry.

*The portion of discharge attributed to ground water seepage could not be separated from the portion attributed to intake.

mainly in that province.

Table 17 indicates on a provincial basis the water intake by the three mineral sectors. British Columbia, Ontario and Quebec, in that order, had the highest water intake in the metal mining group. Alberta had by far the largest intake in the mineral fuels sector. Saskatchewan had the largest intake in the non-metal mines sector due largely to its potash industry.



Oil and natural gas reported the largest gross use of water in the mineral industry.

Table 17

Water Intake in the Mineral Industry by Province and Mining Group – 1981

	Intake	Metal Mines	Mineral Fuels	Non-Metal Mines
Newfoundland	58	58	–	–
Nova Scotia	12	2	1	9
New Brunswick	15	15	–	–
Quebec	107	104	–	3
Ontario	124	108	–	16
Manitoba	13	13	–	–
Saskatchewan	31	8	–	23
Alberta	139	–	132	7
British Columbia	124	116	7	1
Yukon	10	10	–	–
Northwest Territories	15	15	–	–
Total	**648**	**449**	140	59
% of Intake	100	69	22	9

Table 18 reveals the source of intake water used in the mineral industry. It shows that fresh water represents 98% of the water intake by the industry. Of the total amount, 74% is self-supplied from surface sources while another 9% comes from self-supplied ground water sources. Public water works provide only 8% of the industry's intake. While brackish water meets less than 2% of the industrial needs, it is seen to be important to non-metal mines, meeting 15% of that group's needs. Wells are the principal source of intake for the mineral industry in the Northwest Territories and for more than 10% of intake in British Columbia and Saskatchewan. The industry in New Brunswick, Manitoba and Yukon Territory uses little or no ground water.

Table 18

Source of Intake Water in the Mineral Industry – 1981

(millions of cubic metres per annum)

		Fresh Water				Brackish Water		
		Self Supplied						
	Total	Surface	Ground	Public	Other	Ground	Tide	Other
Mineral Group								
Metal Mines	449	321	41	45	42	–	–	–
Mineral Fuels	140	126	12	1	1	–	–	1
Non– Metal Mines	59	34	9	7	–	–	6	3
Total	**648**	**481**	**61**	**53**	**43**	–	**6**	**4**
Province								
Newfoundland	58	57	1	–	–	–	–	–
Nova Scotia	12	4	1	1	–	–	6	–
New Brunswick	15	12	–	–	3	–	–	–
Quebec	107	66	9	30	2	–	–	–
Ontario	124	102	11	10	1	–	–	–
Manitoba	13	13	–	–	–	–	–	–
Saskatchewan	31	19	4	5	–	–	–	3
Alberta	139	128	9	1	–	–	–	1
British Columbia	124	65	17	5	37	–	–	–
Yukon	10	10	–	–	–	–	–	–
Northwest Territories	15	5	9	–	1	–	–	–
Total	**648**	**481**	**61**	**53**	**43**	–	**6**	**4**
% of Total Intake	100	74	9	8	7	–	1	1

The main purposes for water use in the mineral industry are shown in Table 19. Processing, which accounted for 442 million m³ (68%) in 1981, was by far the largest use. Next was cooling, condensing and steam which for 1981 required 174 million m³ or almost 27% of the total intake for that year. British Columbia reported the highest use of water in processing while Alberta not only had the highest use in cooling, condensing and steam but it was the only one in which this use exceeded the corresponding water use for processing. The mineral fuels sector shows this same tendency which is understandable since it is largely used in Alberta (Table 17). Sanitary services accounted for only 3% of intake water.

Less than one third of the water intake in the mineral industry required treatment (Table 20). Screening was the main treatment to which 29% of the intake water was subjected. Chlorination and disinfection were needed for only 21% of the intake water. Other treatment forms were also applied but each involved intake amounts totalling less than 10% of the total. Metal mines undertook to screen, chlorinate and disinfect about 20% of their total intake water and non-metal mines did the same with about 12% of their intake water. Screening was by far the main treatment in the mineral fuels group with more than 60% of intake processed in this way.

Table 21 indicates the approximate costs of acquiring the water (most of which was self supplied), treating the intake water, recirculating the water, and subjecting it to further treatment at the discharge stage. Treatment of discharge water in the metal mines sector constituted the largest individual cost while the treatment of mineral fuels intake water was next highest.

Table 19

Purpose of Water Use in the Mineral Industry – 1981

(millions of cubic metres per annum)

	Intake	Processing	Cooling Condensing and Steam	Sanitary Services	Other
Metal Mines	449	342	84	16	8
Mineral Fuels	140	67	69	2	1
Non-Metal Mines	59	33	21	4	1
Total	**648**	**442**	**174**	**22**	**10**
Newfoundland	58	43	14	2	–
Nova Scotia	12	9	2	–	–
New Brunswick	15	9	2	–	3
Quebec	107	84	15	5	2
Ontario	124	76	45	3	–
Manitoba	13	7	3	1	2
Saskatchewan	31	22	7	2	–
Alberta	139	62	73	2	1
British Columbia	124	107	12	6	–
Yukon	10	9	1	1	–
Northwest Territories	15	14	–	1	–
Total	648	442	174	22	10
% of Intake	100	68	27	3	2

Table 20

Treatment of Water Intake in the Mineral Extraction Industry – 1981

(millions of cubic metres per annum)

Mineral Group	Total Intake	Screening	Chlorination, Disinfection	Filtration	Corrosion, Slime Control	Hardness, Alkalinity Control	Other
Metal Mines	449	92	95	20	18	9	13
Mineral Fuels	140	85	36	35	23	23	3
Non-Metal Mines	59	8	7	2	3	1	–
Total	**648**	**185**	**138**	**57**	**44**	**33**	**16**
Province							
Newfoundland	58	54	39	15	–	–	–
Nova Scotia	12	6	–	–	–	–	–
New Brunswick	15	–	6	–	6	–	–
Quebec	107	10	9	3	1	4	7
Ontario	124	1	26	1	12	3	6
Manitoba	13	–	5	–	–	–	–
Saskatchewan	31	5	6	2	2	1	–
Alberta	139	85	36	35	23	22	3
British Columbia	124	20	7	1	–	3	–
Yukon	10	2	–	–	–	–	–
Northwest Territories	15	2	4	–	–	–	–
Total	**648**	**185**	**138**	**57**	**44**	**33**	**16**
% of Total Intake	100	29	21	9	7	5	2

Table 21

Water Costs in the Mineral Industry – 1981

(millions of dollars)

	Intake				Discharge Treatment
	Acquisition	Treatment	Recirculation	Total	
Metal Mines	6.9	1.3	5.2	13.4	12.4
Mineral Fuels	2.0	9.5	3.7	15.2	1.8
Non-Metal Mines	2.6	0.4	1.0	4.0	0.2
Total	**11.5**	**11.2**	**9.9**	**32.6**	**14.4**
Indicated cost per m³(cents)	1.8	1.7	0.4		1.0

Agricultural Water Use

Water is an essential component for agricultural production whether for plant growth, livestock production or agricultural processing. Although Canada's farmland receives adequate precipitation for native plants and most crops, productivity can be enhanced by augmenting natural rainfall through irrigation. In certain areas such as southern regions of British Columbia, Alberta, Saskatchewan, Manitoba and Ontario, productivity has been increased enough to offset the costs of irrigation.

A 1976 survey conducted by Environment Canada found that Canada's farm area totalled 67 million hectares (ha), a decline of 1.4 million ha from 1961. Despite this declining land base, the amount of agricultural production in Canada has been generally rising through the use of improved crop varieties, greater use of chemicals, improved farming techniques and more intensive use of the land.

Investment in irrigation is one method which makes growing of new crops possible and increases productivity, thereby tending to compensate for the loss of productive land to urbanization and farming practices.

The writeup that follows will tend to discuss the stage of irrigation development in Alberta more often than the other provinces, because Alberta contains more than half of Canada's irrigated farmland, and has produced a clearer picture of its stage of irrigation development.

Livestock accounts for about 12% of all water withdrawals for agriculture.

Area Under Irrigation in Canada

Table 22 reveals the extent of irrigation in Canada during 1970 and the corresponding values for irrigation during 1980 in the western provinces. Statistics Canada did not publish total irrigation quantities for Atlantic Canada, Quebec and Ontario for 1980 because the data collected were unreliable. The area under sprinkler systems was seen to increase in most provinces during the decade, but it is not known how much of this increase was at the expense of other irrigation methods.

Agricultural production in Canada has been generally rising despite a declining land base devoted to agriculture.

Table 22

Area Under Irrigation in Canada – 1970 and 1980

(hectares)

	With Sprinkler Systems		Total Area Irrigated	
	1970	1980	1970	1980
Newfoundland	16	9	50	u
Prince Edward Island	58	23	219	u
Nova Scotia	322	605	755	u
New Brunswick	167	346	1 266	u
Quebec	4 535	5 989	37 594	17 000e
Ontario	23 029	32 127	40 256	40 256e
Manitoba	659	6 403	2 966	6 935
Saskatchewan	2 549	26 149	31 359	70 700e
Alberta	51 150	290 482	217 450	393 969
British Columbia	32 422	82 706	89 432	100 475
Total	114 907	444 839	421 347	629 335

u – data unreliable

Source: Statistics Canada, except for values marked 'e' which are estimates obtained from an internal Environment Canada study.

Water Use For Irrigation and Stockwatering

Table 23 contains estimates of water use for irrigation determined on the basis of irrigated areas and unit quantities of water (coefficients) representing annual use per hectare. Due to incomplete data, only the irrigation areas of Western Canada are available for 1981 with any certainty; water use for irrigation in Atlantic Canada is known to be very small and was not estimated.

The coefficients of annual water use per hectare for the Prairie Provinces were derived from the water demand study of the Prairie Provinces Water Board. Coefficients for other provinces were derived from other published data or were estimated in consultation with experts in the field of agriculture.

Stockwatering estimates, also given in Table 23, were calculated using the population totals of livestock and the coefficients of annual average water use for each category. Statistics Canada provided the livestock figures for 1981 and the Prairie Provinces Water Board study supplied the coefficients which are given in Table 24.

As would be expected, Alberta, with by far the largest area under irrigation (more than the rest of the other provinces combined) used about 68% of the irrigation water in 1981 and a significant proportion of the stockwatering withdrawals as well. British Columbia and Saskatchewan also rank high in terms of the amount of water for irrigation. In contrast, the relatively large withdrawals in Ontario and Quebec are attributed in the main to stockwatering, as are the corresponding totals for the Atlantic Provinces and Manitoba.

Table 23

Estimates of Agricultural Water Withdrawals – 1981

(in million of cubic metres per annum)

	Stockwatering	Irrigation	Total
Newfoundland	–	–	–
Prince Edward Island	3	–	3
Nova Scotia	5	–	5
New Brunswick	4	–	4
Quebec	68	14	82
Ontario	88	60	148
Manitoba	31	21	52
Saskatchewan	50	262	312
Alberta	90	1 884	1 974
British Columbia	21	524	545
Total	**360**	**2 765**	**3 125**

Source: An internal study commissioned by Environment Canada.

Table 24

Major Categories of Livestock and their Respective Daily and Annual Water Use Coefficients

Type of Livestock	Water Use Coefficients for Livestock	
	Litres/Day/Head	m^3/Year/Head
Milk Cows (2 yrs. old and over)	154	56.21
Steers (1 yr. and over)	51	18.62
Bulls (1 yr. and over)	97	35.41
Calves (under 1 yr. both male and female)	25.25	9.31
Other cattle (over 1 yr. and not included above)	64	23.36
Pigs	6	2.19
Sheep	3.5	1.28
Horses	68	24.82
Hens and chickens	0.28	0.10
Other Poultry (turkeys, geese, ducks)	0.5	0.18

Source: Historical and Current Water Uses in the Saskatchewan-Nelson Basin Water Demand Study

Investment in Irrigation in Canada

Investment made for private irrigation can range from $60/ha for flood schemes to $2000 per ha with intensive sprinkler or drip irrigation. All farmers benefit from low cost agricultural loans and free services. Generally, private irrigation schemes are small involving little investment per hectare; large, high-investment projects are usually publicly sponsored.

In Atlantic Canada, Quebec and Ontario, private irrigation systems prevail. In 1970, 6621 farms reported a total of 80 140 hectares (Table 22) including 2884 farms (28 127 ha) with sprinkler systems. The corresponding 1980 value for all farms with irrigation is not available but the 1980 statistics for farms having only sprinkler installations revealed that sprinkler systems were in use on almost 3500 farms in Eastern Canada, and the area irrigated with sprinklers had grown to about 39 100 ha.

In Western Canada, holdings are much larger than those in the East. In 1970, the 10 543 farms reporting served a total irrigation area of 340 000 ha. Statistics for 1981 reveal that the total number of farms had grown to 12 425 and the area irrigated to 572 079 ha. In the West, the field costs for irrigation are met by the farmers, as is also the case for eastern farms. But large proportions (up to 85%) of irrigation investment for conveyance systems, dams and reservoirs in the West are borne by provincial governments.

Alberta has already indicated its intention to expand its water resources and irrigation development program in Southern Alberta. The program is expected to involve an overall expenditure of $334 million for the development of major water conveyance and storage systems and assistance in the rehabilitation and upgrading of water distribution systems within the thirteen irrigation districts.

The cost of irrigation to the farmer will vary considerably from one part of Canada to another. To illustrate, farmers in most irrigation districts in Alberta pay a one-time fee ranging from no charge up to $124 per hectare as a contribution to capital costs to deliver the water to the farm. As well, they will have an annual water rate ranging from $3.70 to $24.70 per irrigable hectare, regardless of whether the water is used, and any costs for farm irrigation equipment. The farmer selects the crop and there is no price differential by crop. Generally, no economic incentives are used to increase irrigation efficiency but the licence for water allocation can be withdrawn if water is consistently misused or under-utilized.

It is apparent, therefore, that substantial investment funds are needed to expand and develop irrigation projects. Good irrigation can augment and expand the total agricultural economic development of an area but, before deciding on such involvement, governments will be compelled to collect information on existing conditions and to carefully assess the social and economic as well as the environmental benefits and costs of irrigation.

Irrigation Crops

Cropping patterns differ markedly among Canadian irrigation districts. Some districts have a relatively large proportion of their irrigated acreages under forage crops. Other districts devote a major proportion of their irrigated areas to grains. The diversity of crop grown and the yields achieved on irrigated farms are considerably greater than the corresponding figures for dryland farms.

Recent British Columbia government studies indicate that there are approximately 607 000 ha of cultivated land in the province. Of this total, about 16% (100 475 ha) is irrigated for the growing of fruit and vegetable crops and for the production of hay used as winter feed in the beef industry. The introduction of commercial fruit growing under irrigation in 1890 provided the transition from cattle to fruit production.

Southern Alberta is the location of the major irrigation projects in Canada. The larger irrigation crops in this area include grains (wheat, barley, oats and flax); forage crops (alfalfa, grass, and clover hay and tame pasture); oilseeds (flax and rapeseed); and specialty crops (sugar beets, potatoes and various vegetables). Statistics for these crops in the major irrigation districts of Alberta are shown for 1980 in Table 25. The crops listed there account for approximately 80% of the total district irrigation in Alberta.

In southern Saskatchewan, limited water supplies have restricted the development of large irrigation districts. Irrigation is mainly used to produce hay in the drier areas of the province.

Manitoba has fewer areas of low rainfall than the other Prairie Provinces; hence irrigation development has been limited to relatively small areas of vegetables, canning crops and some hay production.

A significant expansion in irrigated lands may be possible in the three Prairie Provinces if improvements and additions are made to local storage and conveyance facilities and if the trend toward more efficient water use is continued. Provincial funds have been approved for major irrigation works in Southern Alberta. Manitoba and Saskatchewan have under consideration increased storage and conveyance works in the South Saskatchewan, Souris and Assiniboine River basins.

In Ontario, irrigation is practised in the tobacco and soft-fruit growing areas of Southern Ontario, mainly in the Lake Erie basin. About 10% of the total Canadian irrigated area is in Ontario and, since it is Canada's most populated and industrialized province, water for irrigation will be subject to intense competition from other water users in the future.

In Quebec, considering the size of the province, irrigation is practised on a relatively small scale and is mostly confined to the tobacco intensive areas near Montreal. Despite poor water quality in many areas, Quebec has ample water resources to meet all current and projected irrigation needs.

Irrigation plays a minor role in farm management in the Atlantic Provinces due in part to the humid climate. Water withdrawals for irrigation purposes are relatively small since less than 1% of Canada's total irrigated land is located in the Atlantic Provinces and only 0.5% of all crops in the region are irrigated. Supplemental irrigation is used in Nova Scotia's apple-growing regions but it is unlikely that irrigation will ever be used extensively in the region. High-valued crops such as strawberries, tobacco, vegetables as well as oats, hay and grain are irrigated.

In Eastern Canada, irrigation is used not only to overcome moisture deficiencies but also for frost protection and as a means of applying liquid manure. Irrigation of high value crops such as tobacco and early potatoes is expected to continue but little increase in the number of hectares irrigated is expected.

In Western Canada the provincial governments have attempted to intensify agricultural production by increasing livestock and specialty crops to enable the secondary industrial sector to expand. Significant growth in irrigation is expected in Western Canada.

Table 26 indicates the growth in water use for irrigation over the past three decades on the prairies. In both Saskatchewan and Manitoba, irrigation water uses appear to have trended upwards in a relatively uniform manner. The figures for Alberta, however, with a much larger area under irrigation, show the influence of climate upon water use. The figures show that the current high use of water for irrigation in Alberta dates back to the early 1960s; lesser amounts of irrigation water use in later years, especially 1978, suggest some years had higher than average precipitation, which reduced the demand for water from the levels of other years. Technological changes in Alberta also contributed to the levelling off in water use for irrigation over the past two decades. During the 1960s, farmers began to replace their old irrigation systems with more efficient sprinkler systems, enabling them to attain greater crop productivity with a reduced input of water. This is verified by water use rates. For example, district irrigation used 6.8 m³ per 1000 ha in 1961 compared with 4.7 m³ per 1000 ha in 1976. A continuation of this trend is likely if irrigation (the largest consumer of water) and other water users on the prairies are to expand in the future without growing shortages.

Table 25

Irrigated Hectares, Average Yield, Average Farm Price and Value of Production of Principal Field Crops for Major Irrigation Districts in Alberta – 1980*

Crop	Irrigated Hectares	Yield Per ha.	Production	Farm Price per Unit	Value of Production
			Bushels		
	('000)		('000)		('000)
Wheat	80.9	148	11 978	$ 5.24	$62 765
Oats	5.3	222	1 182	1.86	2 199
Barley	71.6	210	15 076	2.95	44 474
Mixed Grain	12.5	210	2 634	2.78	7 321
Flax	10.1	99	1 014	8.60	8 724
Rapeseed	9.3	99	932	6.25	5 827
			Tons		
Potatoes	4.0	32	126	104.00	13 063
Sugar Beets	13.8	42	572	49.90	2 8 555
Tame Hay	72.4	10	717	74.00	53 058

* Irrigation districts include Bow River, Eastern, Lethbridge Northern, Magrath, Raymond, Saint Mary River, Taber, United and Western.

Source: Acreage and yield data – Regional Economics Branch, Alberta Agriculture; Price data – Statistics Branch, Alberta Agriculture.

Table 26

Growth in Gross Water Use for Prairie Irrigation

(millions of cubic metres per annum)

	1951*	1961*	1971*	1976	1978**
Alberta	670 369	2 336 372	1 989 780	2 258 497	1 541 307
Saskatchewan	103 972	117 188	160 242	266 494	302 390
Manitoba	40 300	40 406	47 103	54 126	57 439
Total	**814 641**	**2 493 966**	**2 197 125**	**2 579 117**	**1 901 136**

*Saskatchewan and Manitoba figures are for 1950, 1960 and 1970
**Manitoba figures are for 1979

Source: Prairie Provinces Water Demand Study.

Irrigation's Benefits are Widespread

Irrigation has been carried on in Canada since 1879, and has had a proven benefit in increased productivity well beyond the agricultural community.

One would think that the farm owner should be the prime benefactor from irrigation, but researchers have found this is not the case. In any reckoning of the benefits of irrigation, those that accrue to the primary producers, the farmers themselves, are counted only as a part of the total, and a minor one at that. Usually considered much more significant are the indirect secondary and even tertiary benefits either induced by irrigation (for instance, the labour, farm equipment and so on needed to do the job) or those stemming from irrigation (such as the processing and marketing of some of the specialty crops). Benefits of investment in irrigation create a ripple effect through the entire economy.

Outlook, Saskatchewan, is a community that has greatly benefitted from irrigation. Located in the South Saskatchewan Irrigation District of Saskatchewan, Outlook has become the main centre for the largest block of irrigated land in the province (about 16 200 ha). Before irrigation was installed in the late 1960s, Outlook's population, which totalled 600, was declining, and yields of hard red spring wheat in surrounding areas were 45-49 bushels per hectare. Subsequently, irrigation has made it possible to grow a variety of crops, and hard red spring wheat yields 125-150 bushels per hectare. As well, the population has expanded to 2200 and retail sales are double those of similarly sized communities elsewhere in the province.

There is no doubt that Outlook has benefitted greatly from irrigation. But experts caution that while irrigation can spell success for the farmer and his region, it nevertheless requires a substantial commitment of time, effort and money.

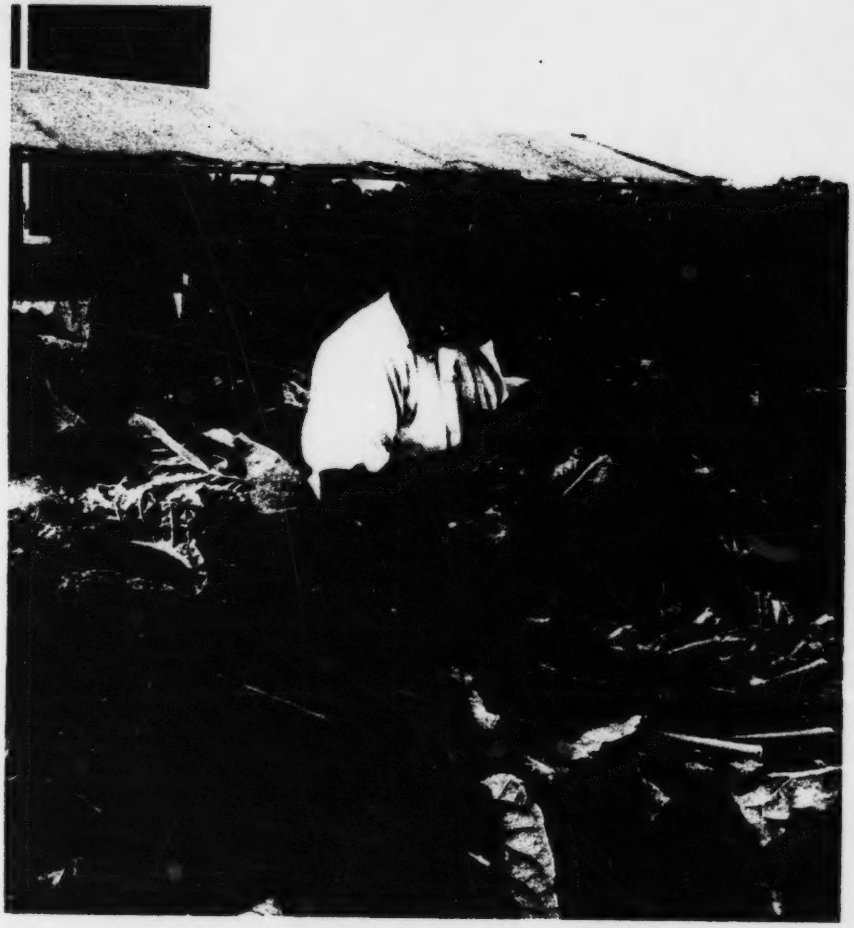
Referring again to Alberta, the 1976 gross value of production on the 380 400 ha of irrigated land was $175 million, or $460 per ha. Had these areas not been irrigated, but retained as dry-land farm instead, the value of production would probably have been $30 million, or $79 per ha. Thus the value added by irrigation can be quite significant.

Future Water Uses

Agricultural water demands are expected to increase significantly in the next two decades, especially if Canada increases its export of foods. A preliminary study of Canada's water supply and demand balances conducted in 1980 by Environment Canada showed that although overall supply will far exceed total demands in Canada by the end of the century, there are certain regions of the country where scarcities have already appeared and where crises will probably emerge in the years ahead. There are in fact, five river basins where current and future demands either exceed or are within 20% of available monthly flow. These basins are the Okanagan, Milk, North Saskatchewan, South Saskatchewan, and Red-Assiniboine. More study is evidently needed to pinpoint the accuracy of the preliminary figures for demand-supply imbalances.

The development of large-scale irrigation projects can be a stabilizing economic development measure facilitating farm diversification. Irrigation serves to relieve the stress on the economy in times of agricultural drought and provides the basic resources for increasing agricultural value-added industries. In this way, the agricultural economy becomes more diversified and stable by ensuring production of high-value crops regardless of variations in precipitation.

Sprinklers meet by far the largest irrigation needs in Canada.



Tobacco is one high-valued crop especially suited to irrigation.

The main expansion of irrigated area in Canada is expected to take place on the prairies. Alberta, which holds the leading role in Canada in terms of irrigated area and in the production of irrigated crops, has a large potential for large scale irrigation development, as has Saskatchewan. To illustrate, in Alberta, there is a potential of some 607 000 ha of additional lands that can be irrigated, of which 202 350 ha can be developed for irrigation with existing river flows. To attain this latter irrigable area (202 350 ha), not only would more effective and efficient management of available water supplies be necessary, but upgrading of present distribution systems and construction of new storage reservoirs on the Milk, Bow and Oldman rivers also would be necessary in order to meet increasing demands and still accommodate inter-provincial and international apportionment commitments.

Applying the Water

There are three basic ways of applying water to the soil: surface, sprinkler and subsurface. The method of irrigation depends upon the crop to be grown, the type of soil, the slope of the land and the amount of water available. The surface and sprinkler methods are the most common methods used.

With surface irrigation, water is applied by gravity over the surface of the field. When using sprinklers, water under pressure is sprayed into the air, to fall like rain. In the subsurface approach, water is applied beneath the surface, wetting the soil surface very little, if at all.

As shown in Table 22, sprinklers meet by far the largest irrigation needs in Canada. Sprinklers can be used on lands that are difficult or impossible to irrigate by surface methods. Also, sprinklers provide better control in the application of small amounts of water and make it easier to convert from dryland to irrigation farming, thus tending to compensate for the higher cost of sprinkler irrigation.

If maximum benefits from irrigation are to be realized, an irrigation farmer must pay careful attention to both the timing of water application and the amount of water supplied. The amount of irrigation water needed depends upon the soil moisture levels established by the counteracting effects of precipitation and evapotranspiration. When the evapotranspiration needs cannot be met by precipitation, moisture stored within the soil is used. As soil moisture decreases, plants extract this water with increasing difficulty. In order to keep plant productivity high, extra water must be supplied by irrigation, usually beginning in June or July.

The seasonal requirements for water depend upon the crops grown. Cereal crops such as wheat have high daily water requirements, and require most of their water during the flowering and grain-forming stages. Irrigation of cereal crops could cease after about July 20 without a serious reduction in yield. Water requirements for pasture crops extend over longer periods of time than is the case for cereal crops. Some specialty crops such as suger beets have lower daily water requirements but high total water requirements because of the longer period of time over which water is needed.

Water Quality

Irrigation affects downstream water quality directly by returning water of reduced quality to the water course and indirectly by removing large quantities of water.

Irrigation water, like any other naturally occurring water, contains salts. The commonest salts in the major irrigation areas of Canada are sodium sulphate, calcium sulphate and magnesium sulphate and each reacts differently in different soils and under different growth conditions. The usual result of irrigation is a rise in the natural water table. With natural salts already present in the soil and more applied through irrigation, the cumulative effect is a greater salinity in surface soils. From an efficiency perspective, the concentration of salts in the upper soil zone reduces permeability and infiltration rates and can only lead to an overall lowering of the productivity of the land.

Water Use in the Thermal Power Industry

Thermal-electric (steam) generating stations require enormous quantities of water for condenser cooling while minor amounts are required for boiler feed and sanitation services in the station.

The cooling use arises because the conversion of fossil or nuclear energy to electricity is inefficient and much of the calorific input remains unused. These extra thermal units must then be absorbed by a continuous flow of cooling water circulating through the condenser. Vast quantities of intake water are needed which eventually are discharged to the environment in a heated state.

Diesel units do not need a continuous source of water for cooling and, therefore, are excluded from the water statistics which follow. For the same reason, the net generating statistics contained in accompanying tables exclude electricity generated by diesel units.

Tables 27 and 28 display the net electrical generation and water use in the thermal power industry in 1981. Both tables also show the respective figures for recirculation, gross use and discharge. As noted in Table 27, only Alberta employed recirculation to reduce demand on the water supply available. Without recirculation, thermal power generation in Alberta would have required another 1868 million m^3 of water in 1981, almost tripling the actual volume of intake.

Table 27 reveals that Ontario alone accounted for 62% of the net generation in the thermal industry in 1981 and for 70% of the gross use of water. Alberta ranked second with 20% of the net generation but used only 5% of the intake water, reflecting the benefits of recirculation at two Alberta thermal stations – Sundance and Milner. While reducing significantly the amount of intake water required, recirculation nevertheless resulted in greater consumption of water within the system. The 44 million m^3 of consumption in Alberta (4.3% of intake) was proportionately higher than the 36.1 million m^3 (0.2% of intake) in Ontario which used once-through systems. This disproportionate consumption can be explained by the fact that the consumption in Ontario and most other provinces reflects only in-plant plant consumption whereas the Alberta figure, because of the way it was determined, contains significant amounts of evaporation from cooling ponds at the Sundance and Milner plants.

Quebec is seen to have a large intake of water and a relatively low generation. This was because water was used continually in 1981 at two thermal power plants in Quebec even though generation only took place during a short period in January 1981.

Table 28 reveals that electric power generation by utilities accounted for 97% of the net electric power generation in 1981, with the public sector share being 77%. In terms of gross water use, electric power utilities' share was almost 95%. On the other hand, these same major users (utilities)

Table 27

Net Generation and Water Use in the Thermal Power Industry, by Province – 1981

(in GWh and millions of cubic metres per annum)

	Net Generation	Intake	Recirculation	Gross Use	Discharge	Consumption*
Newfoundland	414	77	–	77	77	–
Prince Edward Island	32	1	–	1	1	–
Nova Scotia	5 732	942	–	942	907	35
New Brunswick	4 203	817	–	817	811	6
Quebec	75	308	–	308	304	4
Ontario	70 728	14 930	–	14 930	14 894	36
Manitoba	378	56	–	56	56	–
Saskatchewan	6 393	766	–	766	741	25
Alberta	22 595	1 024	1 868	2 892	980	44
British Columbia	1 267	360	–	360	342	18
Total	111 817	19 281	1 868	21 149	19 113	168

Water use for heavy water production is included with manufacturing and is not reflected in this table.

*Consumption figures reflect in–plant consumption except for Alberta's (44 million m^3/ annum) which includes a significant amount of evaporation from cooling ponds within the recirculation systems of two large thermal power plants.

Source: 1981 Industrial Water Survey.

Table 28

Net Generation and Water Use in the Thermal Power Industry, by User Category – 1981

(In GWh and millions of cubic metres per annum)

	Net Generation	Intake	Recirculation	Gross Use	Discharge	Consumption*
Electric Power Utilities						
Public	86 226	17 140	–	17 140	17 101	40
Private	17 851	728	1 868	2 596	708	20
Municipal	4 776	298	–	298	274	24
Primary Metal Industries	252	375	–	375	342	33
Chemical Industries	189	316	–	316	290	26
Paper and Allied Industries	2 141	268	–	268	246	21
Wood Industries	131	74	–	74	73	1
Mineral Fuels	38	59	–	59	59	–
Food and Beverages	41	13	–	13	11	2
Textile Industries	26	5	–	5	4	1
Non–Metal Mines	132	4	–	4	4	–
Rubber and Plastics	3	1	–	1	1	–
Metal Mines	10	–	–	–	–	–
Total	**111 816**	**19 281**	**1 868**	**21 149**	**19 113**	**168**

*See Table 27 for footnote re consumption

Source: Industrial Water Survey 1981.

accounted for just half of the total consumption in 1981.

Forced Evaporation

Most thermal-electric (steam) generating stations in Canada employ a once-through cooling system, that is, water is drawn from natural water bodies, passed through the condensers, and then returned to the environment essentially undiminished in quantity but raised in temperature. Some plants, primarily in Alberta, employ cooling ponds within a closed circuit (recycle) system. Cooling water is drawn from the pond and returned to the pond after use via a long flow path designed to give up the heat to the air by convection and evaporation. Fresh water is added to this recycle system from an external source to make up for water lost through evaporation; as well, a percentage of water from the pond is replaced with fresh water from the external source to prevent a build up of salts within the recirculating system. The Sundance Thermal-Electric Station in Alberta has such a recycling system which is fed from the North Saskatchewan River. The water in its system is recycled 70 times before discharge.

As already indicated, the Industrial Water Use Surveys took account of the water consumed within Sundance and Milner plants and forced evaporation from cooling ponds in the plants' systems, thereby enlarging upon consumption for Alberta. The Survey did not, however, consider forced evaporation at once-through stations, nor is it reflected in the statistics herein. Forced evaporation occurs after the water has been circulated through a station's condensers and returned to the natural source in a heated state. Available literature reveals that forced evaporation can range from 0.72 to 2.30 litres per kilowatt-hour for once-through cooling. A value of 1.4 litres/kWh was used by the Prairie Provinces Water Board in a recent study of power generation water uses on the prairies. Adopting such a value for all of Canada would suggest that forced evaporation as a result of the release of heated discharges in thermal (steam) generation would significantly increase the consumption reported in Tables 27 and 28.

Water Intake – Source and Point of Discharge

Table 29 shows that almost all water used in the thermal-electric power industry was self supplied. Only a fraction of 1% was obtained from public water supplies or other sources.

Fresh surface water filled more than 90% of the water needs in the thermal power industry. Most of the remainder (9%) was brackish water from tidal sources. Ground water use was insignificant in the thermal power industry.

After use, most of the water was discharged back to a freshwater body or to a tidewater body. As shown in Table 30, quantities discharged to other points were relatively small.

Table 29

Source of Intake Water in the Thermal Power Industry – 1981

(In millions of cubic metres per annum)

	Fresh Water				Brackish Water	
	Public Water Supply	Self Supplied			Self Supplied Tide Water	Total
		Surface Water	Ground Water	Other Sources		
Electric Power Utilities						
Public	8	15 470	–	–	1 662	17 140
Private	26	702	–	–	1	729
Municipal	3	279	–	16	–	298
Primary Metal Industries	4	343	–	–	28	375
Chemical Industries	1	315	–	–	–	316
Paper and Allied Industries	32	234	1	–	–	267
Wood Industries	1	45	8	–	19	73
Mineral Fuels	–	59	–	–	–	59
Food and Beverages	–	13	–	–	–	13
Other	–	10	–	–	–	10
Total	75	17 470	9	16	1 710	19 281

Source: Industrial Water Survey – 1981.

One concern with thermal power generation is the surplus heat produced and discharged to waterways.

Table 30

Point of Water Discharge in the Thermal Power Industry – 1981

(In millions of cubic metres per annum)

	Public Sewer	Freshwater Body	Tidewater Body	Ground	Artificial Body	Other	Total
Electric Power Utilities							
Public	1	15 431	1 662	–	7	–	17 101
Private	–	707	1	–	–	–	708
Municipal	–	228	–	–	–	46	274
Primary Metal Industries	4	337	–	–	1	–	342
Chemical Industries	1	289	–	–	–	–	290
Paper and Allied Industries	–	99	135	12	–	–	246
Wood Industries	1	45	19	–	8	–	73
Mineral Fuels	–	59	–	–	–	–	59
Food and Beverages	1	10	–	–	–	–	11
Non–Metal Mines	–	–	–	–	–	4	4
Textile Industries	4	–	–	–	–	–	4
Other	–	1	–	–	–	–	1
Total	**12**	**17 206**	**1 817**	**12**	**16**	**50**	**19 113**

Source: Industrial Water Survey 1981

Water Treatment

Screening to remove solids from the water was the main type of intake treatment, with 59% (Table 31) of all intake water being treated in this way. All other types of treatment were applied to 4% or less of the intake water. Statistics on discharge treatment are not available.

Purpose for Water Use

The data collected relating to purpose of the water used were not sufficient to permit a breakdown of the intake according to this category. What is known, however, is that almost all of the water was used for condenser cooling as part of the electric power generating process.

Table 31

Treatment of Intake Water in the Thermal Power Industry – 1981

(In millions of cubic metres per annum)

	Intake	Screening	Corrosion, Slime Control	Chlorination, Disinfection	Filtration	Hardness, Alkalinity Control	Other
Electric Power Utilities							
Public	17 140	9 632	529	130	11	9	11
Private	728	435	–	2	6	2	1
Municipal	298	153	142	–	–	–	–
Primary Metal Industries	375	357	2	1	1	15	11
Chemical Industries	316	316	–	222	1	4	–
Paper and Allied Industries	268	343	26	12	106	28	4
Wood Industries	74	46	–	–	–	–	–
Mineral Fuels	59	59	–	–	–	–	–
Food and Beverages	13	12	–	–	–	–	–
Textile Industries	5	5	5	–	5	5	–
Non–Metal Mines	4	–	1	1	–	–	–
Rubber and Plastics	1	–	–	1	–	–	–
Total	19 281	11 358	705	369	130	64	27
% of Intake	100	59	4	2	1	–	–

Source: Industrial Water Survey 1981

Water Intake – Acquisition and Treatment Costs

Table 32 shows that the acquisition cost of the water and the cost of treating the water were very nearly equal in 1981, with treatment costs being slightly larger. The Electric Power Utilities, which produced most of the net generation, accounted for $14.2 million or about 62% of the total intake cost. Paper and Allied Products was second highest with $4 million or 17% of total cost.

Table 32

Water Costs in the Thermal Power Industry – 1981

(in millions of dollars)

	Intake Acquisition Cost	Intake Treatment Cost	Total Intake Cost
Electric Power Utilities	6.5	7.7	14.2
Paper and Allied Products	1.6	2.4	4.0
Chemical Industries	1.9	0.1	2.0
Mineral Fuels	0.4	0.4	0.8
Primary Metals	0.1	0.5	0.6
Textile Industries	0.2	0.3	0.5
Wood Industries	0.3	–	0.3
Non–Metal Mines	0.1	0.1	0.2
Food and Beverages	0.1	–	0.1
Other	0.1	0.2	0.3
All Industries	11.3	11.7	23.0

Source: Industrial Water Use Survey

Water Transport

Water has played a vital role in transportation and communications, and its contributions in these areas, in turn, have influenced patterns of industrial growth and settlement in Canada. Canada's major river systems permitted relatively easy penetration into the interior of the continent. As the Canadian economy diversified, and as advances were made in the technology of transportation, the character and role of the waterways continually changed.

Cheap water transportation encouraged the export of staple goods to Europe. Fur, timber, and wheat have acted as staples during various stages of the nation's economic growth. The history of the fur trade illustrates the central role water transportation played in resource development. The timber and wheat trades were no less dependent upon water to transport their products to overseas markets.

Shipping has remained a key part of the Canadian transportation network since Confederation. Old dreams of a commercial transportation empire were revived in the form of a planned 'St. Lawrence Deep Waterway'. Improved water transportation, in turn, stimulated Canadian industrial developments. The early mining industry of eastern Canada was confined to areas accessible to transportation facilities, and was able to expand as facilities improved; coal from the Maritimes was able to penetrate the markets of Ontario and Quebec; the St. Lawrence-Great Lakes region became a major iron and steel producer. Low freight rates encouraged the growth of manufacturing industries in the region, as well. Abundant grain crops, the basis of the prairie economy, were shipped to markets by rail and water, via the traditional Great Lakes-St. Lawrence route, or from newer ports such as Vancouver and Churchill. A flourishing export trade in lumber to the Orient opened up to west coast merchants, and following completion of the Panama Canal, to Atlantic merchants. The old Mackenzie Waterway of the fur trade era took on new significance as a transportation link in the economic development of the Canadian North.

With motor and air carriers, railways and pipelines competing, water transport of freight has declined relatively, but not in absolute terms. These alternatives curtailed the demand for any large scale inland water transport undertaking in Canada's emerging nationhood because they were able to operate on a year-round basis while most waterways were closed to navigation for up to five months each year. However, as reflected in Table 33 which shows the extent of the cargoes loaded and unloaded during 1981 at all ports in coastal and international seaborne shipping, water still plays an important role in the transporting of bulky raw materials of Canada's trade.

Although the recession has influenced water transport in the early 1980s in the same way it has all other areas of economic development, water transport continues as a principal water use and as a major competitor with other uses in water development. As well, new ports legislation was proclaimed in February 1983, testifying to the still important role that water transportation plays and will continue to play in Canada's economic life.

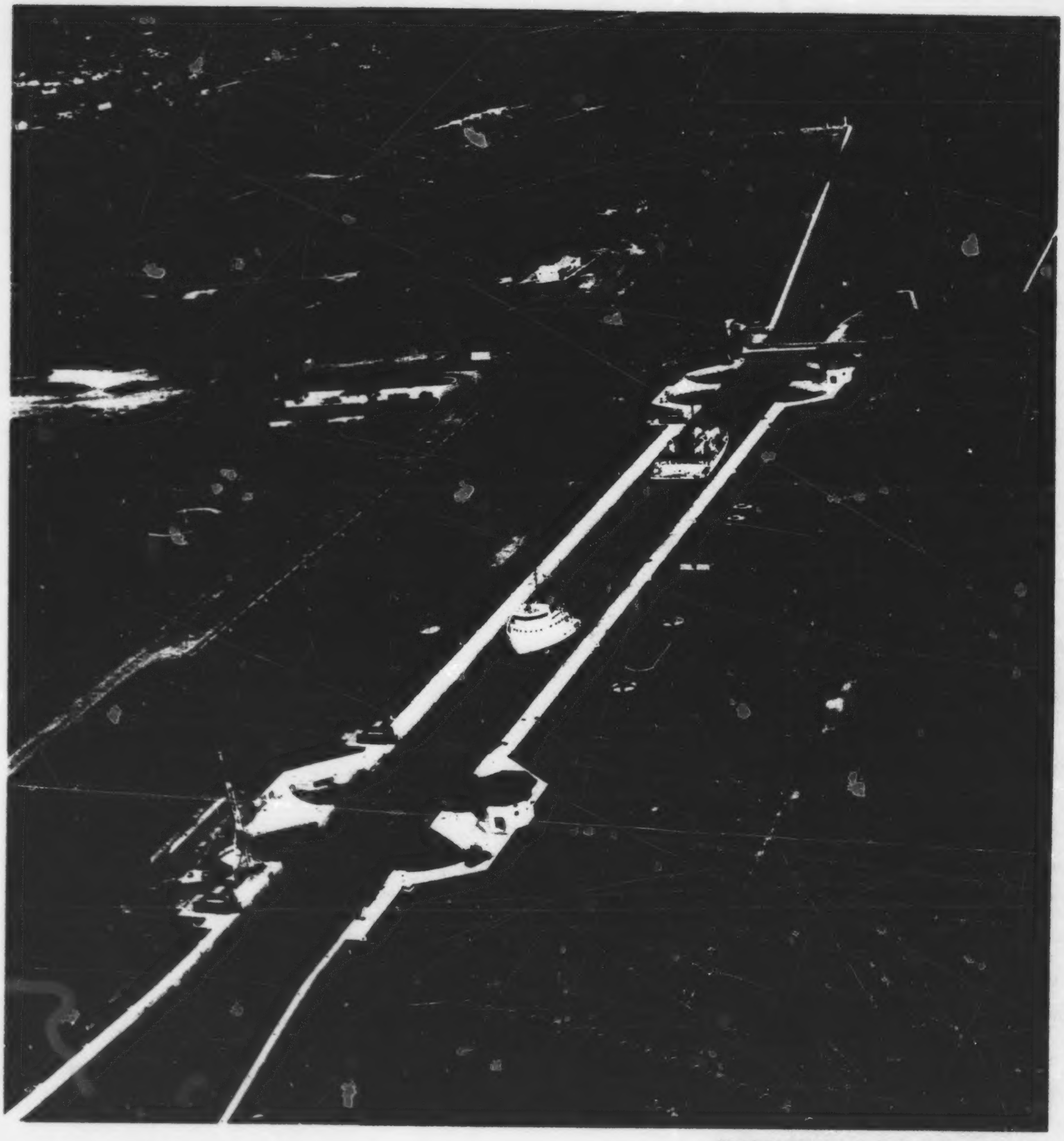
Table 33

Cargoes Loaded and Unloaded at All Ports in Coastal and International Shipping – 1981

(metric tonnes)

	Coastal		International		
	Loaded	Unloaded	Loaded	Unloaded	Total
Newfoundland	2 404 488	574 167	1 482 435	944 722	5 405 812
Prince Edward Island	539 282	17 211	74 032	6 352	636 877
Nova Scotia	2 928 235	3 796 805	8 325 728	5 813 771	20 864 539
New Brunswick	1 250 953	2 128 515	5 470 188	7 206 077	16 055 733
Québec	23 184 189	13 643 932	67 149 753	22 564 756	126 542 630
Ontario	14 867 381	25 031 921	9 072 688	25 655 397	74 627 387
Manitoba	–	18 785	451 475	–	470 260
British Columbia	25 949 869	26 054 737	53 418 779	5 996 814	111 420 199
Northwest Territories	146 696	5 020	–	–	151 716
Total	71 271 093	71 271 093	145 445 078	68 187 889	356 175 153

Source – Statistics Canada



Abundant grain crops, the basis of the prairie economy, are shipped to markets by rail and water, via the traditional Great Lakes-St. Lawrence route, or from ports such as Vancouver or Churchill.

The Canadian Port System

In 1983, the Canadian port system consisted of three groups of commercial ports comprising 1) the Canada Ports Corporation's System, which handled about 50% of Canada's total waterborne commerce, 2) the Harbour Commission Group, which was responsible for about 20% of port tonnage, and 3) Public Harbours and Wharves, whose share was also about 20%. Privately owned port facilities handled the remaining 10%. Although each of the entities continued to provide service at the same level as recent years, new ports legislation was passed in 1982 and proclaimed in 1983 which offers the three types of commercial ports greater participation in regional and national ports planning and a high degree of autonomy to those which are financially self sufficient. How the main provisions of the new legislation are expected to influence operations of the port system is discussed in the following.

1. The Canada Ports Corporation

The bulk of the 1981 ports legislation was devoted to establishing the Canada Ports Corporation which replaces the National Harbours Board (created in 1936) and to describing its structure, its powers and its operation. Known as Ports Canada, the Corporation possesses the powers of a modern-day Crown Corporation. The Canada Ports Corporation Act embodies the objective of the national ports policy and provides for the creation of local port corporations with a high degree of autonomy.

A 17-member Board of Directors has been created to manage the Corporation in accordance with the Act and the national ports policy. Its powers include (with the approval of the Governor-in-Council) the making of bylaws for the administration, management and control of the harbours under its jurisdiction. These bylaws will provide for a realistic level of contracting authority, previously constrained under the National Harbours Board Act. Ports Canada will have the exclusive power to set charges for services within the boundaries of its ports. Harbour dues, however, will continue to be set by bylaw.

Local Port Corporations: Ports Canada ports seeking more autonomous status can apply to the Ports Canada Board. These ports will be considered against the criteria of national and regional significance, local interest in managing the port in question and the likelihood of financial self-sufficiency. After proper review of the applications, and where warranted, Ports Canada will petition the Minister of Transport for the establishment of a local port corporation. The Minister, with the approval of the Governor-in-Council, may then issue letters patent of incorporation under his seal of office.

Local port corporations will have their own boards of directors, whose members are appointed part-time, by Order-in-Council, on the recommendation of the Minister of Transport, after consultation with the Board of Ports Canada.

Local port corporations will be responsible for operating and managing their respective ports, as well as for property management, contracting and tendering, personnel and other operating powers required to administer their ports. They also will originate their own by-laws, for Governor-in-Council approval, on the recommendation of Ports Canada. The local board will be able to appoint its own port manager, who then becomes the chief executive officer for the local port corporation.

Port authorities, established at major National Harbours Board ports in 1971, have provided advice to the Minister on port development. Although not provided for in existing legislation, they were seen as precursors to the local port corporations and local advisory committees established under the Canada Ports Corporation Act. Port authority chairmen played an active role in shaping the new legislation.

From East to West, the ports of Ports Canada are: St. John's, Nfld.; Halifax, N.S.; Saint John, N.B.; Belledune, N.B.; Sept-Iles, Qué.; Chicoutimi, Qué.; Baie des Ha! Ha!, Qué.; Québec, Qué.; Trois-Rivières, Qué.; Montréal, Qué.; Prescott, Ont.; Port Colborne, Ont.; Churchill, Man.; Vancouver, B.C.; Prince Rupert, B.C.

The Board of Ports Canada has undertaken to review all former NHB ports and decide which ports satisfy the criteria for achieving local port corporation status. Those at Montreal and Vancouver were the first ones to be granted local port corporation status in 1983. The Ports of Halifax, Quebec, and Prince Rupert followed in 1984.

Divisional Ports: Ports which do not attain local port corporation status (non-corporate ports) will be operated as divisions of Ports Canada. For these ports, local advisory committees may be established to provide advice to Ports Canada on the development and operation of their ports. These local advisory committees will consist of three to five members, appointed by the Minister, from among those who live in the vicinity of the port.

Financial Management: An objective of Ports Canada is to achieve and maintain a position of financial self-sufficiency. The legislation describes the conditions under which Ports Canada and local port corporations manage their revenues.

Both Ports Canada and local port corporations may borrow money from the government, as long as it is for the purpose of attaining the objective of the national ports policy. There is also a provision in the legislation for the government to give direction to the Corporation for the advancement of national interests, and the Corporation must comply. In keeping with the objective of financial self-sufficiency, however, the government will reimburse the Corporation for losses incurred in complying with such directions, and is required to table such directions in Parliament for public scrutiny.

2. Harbour Commissions

The 1982 ports legislation makes only minor adjustments to the Harbour Commissions Act of 1964, since it is the most modern of existing ports legislation, and already responds in large measure to the objective of the national ports policy.

The amended Harbour Commissions Act incorporates the objective of the national port policy and, in accordance with this objective, harbour commission chairmen will be members of the regional advisory council established for their region.

Another amendment permits any port to transfer by Order-in-Council to harbour commission status. Previously, an amendment to the legislation was required. To become a harbour commission, however, a port will have to be financially self-sufficient, and due consideration will be given to the impact of the transfer on the national and regional port and transportation systems.

The harbour commission ports are:

Oshawa, Ont.; Windsor, Ont.; Thunder Bay, Ont.; Fraser River, B.C.; North Fraser River, B.C.; Port Alberni, B.C.; Nanaimo, B.C., plus Toronto and Hamilton (under separate status).

3. Public Harbours and Port Facilities

The Public Harbours and Port Facilities Act, part of the 1982 ports legislation, consolidates legislation governing some 500 smaller ports previously covered under the Government Harbours and Piers Act, and in the Canada Shipping Act with respect to the proclamation of public harbours and the appointment of harbour masters. The new legislation is made consistent with other ports legislation by defining the powers of the Minister of Transport. The Minister is expected to recommend, to the Governor-in-Council, regulations for the management, control, use, and development of public harbours.

More effective administration and development of public harbours is expected under the new Act which calls for the transfer of responsibility for major maintenance and investment programs from Public Works Canada to Transport Canada. Public Works, however, has been retained as the supplier of design, construction and realty services for public harbours and associated dredging within the limits of these facilities.

The responsibility for the management of this sector remains with the Marine Administration of Transport Canada. A headquarters staff will provide a central focus for port policy and planning. However, the regional staff responsible for operation and management are delegated greater authority and their resources are strengthened to meet the requirements of users. Greater emphasis has been placed on the development of regional capital investment plans to make public harbours a more dynamic element of the national port system.

Consultative Bodies on Port Matters

The 1982 ports legislation contains a provision for the creation of regional advisory councils which are expected to provide an opportunity for effective consultation between different organizations and individuals involved in port activities, and form the basis for sound, coordinated planning and development of the national ports system. Such regional advisory councils are in the process of being considered for establishment in five regions, including Western Canada, Central Canada, Quebec, the Maritimes and Newfoundland. Under the legislation, each regional advisory council will advise the Minister of Transport on planning and development of ports in its region, and on port matters of regional significance.

The Great Lakes-St. Lawrence System

To navigation, this system is basically a deep waterway extending some 3700 km from the Atlantic Ocean to the head of Lake Superior in the heart of North America.

Efforts to turn the St. Lawrence River into a transportation artery that would provide access to the centre of North America were begun in the 18th century. Major construction in this country really began in 1841 with the union of Upper and Lower Canada, which provided the financial base needed to invest in large scale transportation facilities. By 1850, with the construction of the second Welland Canal, a navigable waterway with a minimum depth of nine feet was available from the Atlantic Ocean to the Upper Lakes.

The long history of costly canal construction by Canada was dictated by the need for a viable East-West transportation system that would offset the strong southward pull of the U.S. economy and the alternative routes provided by the Erie Canal and the Mississippi River. Without such a Canadian system, it is doubtful that the kind of economic infrastructure that developed in Canada in the 20th century would have been possible. In short, it was national rather than regional considerations that prompted the development of the St. Lawrence-Great Lakes waterway.

While Canada recognized the need for a larger canal system at the turn of this century, work on the Welland Canal was not completed until 1932. It was known that full benefits of an enlarged waterway could only be realized with the completion of the Montreal to Lake Ontario section, but it took some 50 years of international negotiation before this could be brought to a conclusion with the opening of the present Seaway in 1959.

Construction of the facilities required in the International Section of the St. Lawrence was a joint project of Canada and the United States. Canada built five locks on the Canadian side; one at St. Lambert, another at Cote Ste-Catherine and two in Beauharnois, all in the Province of Quebec, and one at Iroquois, in Ontario. The United States built two locks at Massena, New York.

There was also constant consultation with the provinces as various elements of the project were put together. An earlier agreement with Quebec called for the Beauharnois Canal to be shared for power and navigation purposes. The cost of maintaining this canal is shared by Hydro-Québec and the Seaway Authority.

In the 1950s, works designed principally to provide hydroelectric power, but which contributed to navigation, were built in the International Rapids section between Prescott and Cornwall, Ontario.

Since the commencement of construction in 1954, initial construction and subsequent improvements of the Seaway have cost about $328.5 million on the Montreal-Lake Ontario section, and $285.5 on the Welland section. Included is the Welland By-Pass which was opened to traffic in 1973 because the Seaway recognized the need to replace a narrow winding part of the Welland Canal which bisected the City of Welland, Ontario. The new channel, while contributing to the safer and easier passage of vessels, also removed a serious bottleneck for vehicular traffic in the downtown Welland area. This was achieved by replacing several lift bridges with two major tunnel crossings.

Development of the Seaway has produced a waterway which has inherent advantages, especially in the mass movement of low-valued bulk commodities over long distances. It is not surprising, therefore, that grain, iron ore, coal and other miscellaneous bulk products have accounted for some 90 percent of the total traffic. The almost quarter century that has elapsed since the opening of the Seaway has demonstrated clearly the significant role the system has played in the movement of goods to and from the interior of the North American continent.

The Seaway has stimulated commerce between the various provinces, between Canada and the United States and between Canada and other countries. Its most direct impact is on the shipping and receiving of commodities but its indirect impact is felt by a broad range of activities serving the Seaway system.

The main revenue of the Seaway is generated through tolls which vary according to the cargo being transported and the size of the ship, with the addition of a lockage fee on the Welland Canal. Originally, it was intended that capital and interest would be repaid over 50 years but, by 1977, it was clear what this goal was not attainable. Since then, the federal government has refinanced the Seaway by converting the $625 million debt to equity, by placing a moratorium on the $210 million of interest and by agreeing to cancel this interest debt at some future date. The Authority has been self-sustaining since this refinancing program.

Report on Operations

Table 34 has been prepared to illustrate the quantities and types of products carried on the two sections of the Seaway in 1981 and 1982. It also gives the total number of transits, that is, the total number of partial or complete upbound or downbound passages of vessels through one or more locks of a Seaway Canal, as well as the upbound/downbound traffic split.

In 1982, traffic on the St. Lawrence Seaway was at its lowest level since 1974. Cargo on the Montreal-Lake Ontario section decreased from the previous year by 15.3% to 42.82 million tonnes and vessel transits declined by 5.4% to 4376. Tonnage on the Welland Canal fell to 49.05 million tonnes, 16.7% lower than the 1981 level, while transits decreased by 13%, to 5184. The decline in Seaway traffic in 1982 is mainly attributed to the prolonged world-wide economic recession and, in particular, to the very substantial drop in steel production in the United States.

Seaway authorities recently funded a study by a consortium of U.S. and Canadian consultants for the purpose of producing traffic forecasts to the year 2000. This study provided a basis for reviewing the capacity situation and deciding upon improvements which may be required to stay ahead of traffic demand. The overall conclusion is that traffic flows on both the Welland and Montreal-Lake Ontario sections will continue to increase, but at a lower rate than in the previous historical period. Although tonnage is expected to grow over time in both the upbound and downbound directions, the ratio of downbound to upbound traffic is projected to increase over the forecast period. In other words, the ratio (iron ore backhaul from the Lower St. Lawrence/downbound grain movements) is expected to decrease, and the overall efficiency and economy of the Seaway system should decline somewhat over the forecast period for both the carriers and canal operators. Some of the highlights in 1982 are discussed in the following.

Grain: Canadian grain traffic in 1982 reached a record level of 16.47 million tonnes on the Welland Canal, 17% higher than the 1981 level, reflecting both a heavy grain export program and an improved performance by the Canadian grain transportation and handling system.

Despite record Canadian grain shipments through the Seaway in 1982, combined Canadian-U.S. movements decreased by 1.5% from 1981 to 25.19 million tonnes on the Welland section, while the Montreal-Lake Ontario section showed a slight

Table 34

Traffic in the St. Lawrence Seaway

General Statistics	1981	1982
Montreal-Lake Ontario		
Total cargo (tonnes)	50 569 257	42 815 314
Total vessel transits	4 628	4 376
Traffic split (%)		
Upbound	37	26
Downbound	63	74
Welland Canal		
Total cargo (tonnes)	58 850 875	49 024 104
Total vessel transits	5 960	5 184
Traffic split (%)		
Upbound	28	18
Downbound	72	82

Cargo Traffic by Principal Commodity
(millions of tonnes)

Commodity	Montreal-Lake Ontario		Welland Canal	
	1981	1982	1981	1982
Grain	24.46	24.27	25.57	25.19
Canada	(13.51)	(15.95)	(14.10)	(16.47)
United States	(10.95)	(8.32)	(11.47)	(8.72)
Iron Ore	12.93	7.43	13.74	7.02
Coal	1.68	1.15	6.58	7.14
Other Bulk	8.09	6.79	10.23	7.66
General Cargo	3.41	3.18	2.73	2.01
	50.57	**42.82**	**58.85**	**49.02**

Source – St. Lawrence Seaway Authority.

decline of 0.8% to 24.27 million tonnes. The softening of this traffic is attributable to the weakness of the U.S. grain exports via the Seaway route which shrank by 24.0% to only 8.32 million tonnes – the lowest level since 1976. This downward trend of the past three years reflects a number of factors, the most significant of which is the greatly increased capacity of the U.S. rail and barge route via the Mississippi, which, in turn, is a reflection of the decline in demand for U.S. transportation services resulting from the period of economic recession. Consequently, very low barge and rail rates on the Mississippi route have combined to attract a greater share of U.S. grain exports than had been the case prior to the onset of the recession. Until competitive routes in the United States are again operating at or near capacity, it is unlikely that the Seaway route will regain its former share of U.S. grain exports.

Iron Ore: Unlike grain traffic, Seaway iron ore movements in 1982 experienced a substantial decrease from 1981 levels. On the Montreal-Lake Ontario section, they dropped by 42.5% to 7.43 million tonnes, and on the Welland by about 49% to only 7.02 million tonnes. This sharp decline was due almost entirely to the prolonged economic recession in 1982 which severely depressed the automotive and steel industries in North America.

Compared to 1981, steel production in the United States was down by 40% to only 66 million tonnes in 1982 and capability utilization fell to 47%. Imports of iron ore totalled about 13.4 million tonnes, the lowest since 1954. This decline contributed to the shutdown of several steelmaking facilities as well as iron ore mines in Canada and the United States. Consequently, upbound shipments of Quebec-Labrador iron ore to the U.S. Lake Erie ports reached only 5 million tonnes compared to 10.2 million in 1981. Moreover, the collapse in steel demand also affected steel producers in Canada. Downbound iron ore to these facilities through the Welland Canal dropped from 3.2 million to only 1.7 million tonnes.

Coal: Seaway coal traffic depends mainly on the demand from Hamilton steel plants and Ontario Hydro's coal-fired stations located on Lake Ontario. In addition, since 1981, U.S. coal has been exported to Western Europe via the Seaway when capacity problems at U.S. East Coast ports enabled lake ports to capture a small share of the then booming coal export market. This new flow contributed to the substantial increase in coal shipments on the Montreal-Lake Ontario section, from 0.2 million tonnes in 1980 to 1.68 million tonnes in 1981. However, the recession in Europe, coupled with declining world oil prices, reduced this traffic to 1.15 million tonnes in 1982.

On the Welland Canal, 1982 coal traffic increased by 8.6% over the 1981 level, but this higher level was not attained in 1983.

Improving the Seaway

Although it has been improved over the years, the Welland Canal is still the bottleneck of the Seaway system. The canal's eight locks and several channel restrictions form a series of constraints over its short length of 23 nautical miles. The surge of traffic resulting from the opening of the St. Lawrence section of the Seaway in 1959 brought the Welland section its first major capacity test and a series of modifications followed. After another leap in traffic in 1964, a number of improvements were made to increase the efficient usage of the canal including the construction of the Welland By-Pass channel. These improvements, combined with the introduction of new maximum-sized vessels by ship owners have enabled the tonnage capacity of the Welland to double since the mid-'60s. They have, as well, produced benefits for the shipping industry in the form of faster and safer vessel transits. Average transit time through the Welland Canal is now of the order of 13 hours compared to a peak of over 24 hours in 1964.

Another limitation of the Seaway is the interruption due to severe winter conditions. When the Seaway opened in 1959, the navigation season extended from April 15 to November 30. Improvements made by the Authority have increased this period from about April 1 to about December 15. The actual dates are dependent upon ice conditions. While some additional capacity could be obtained by lengthening the navigation season, recent economic studies of Canadian benefits and costs for further extensions indicate that improvements to the present 8 1/2 month season are justifiable to firm-up the season, but extending it much beyond that period could not be supported on a cost-benefit basis.

The current assessment of Welland Canal capacity indicates that without any further improvement, adequate service would no longer be available by about the year 2000. There is also the possibility of demand surges that could precipitate earlier periods of congestion. In response to this situation, the Authority has undertaken a program of physical improvements, including the widening of a long section of the channel which will permit vessels to pass safely where previously this was not possible. The widening, together with other scheduled improvements, is expected to increase the capacity of the canal from an average 30 lockages per day to 34. A traffic control improvement program is now being developed and will be instituted over the next few years. The objective is to put the traffic control centre's present manually-operated system on a computerized basis which will enable ship scheduling to be pre-planned and arranged to fully optimize canal capacity for any given canal configuration and loading situation. It is evident that one of the most important factors in extending the life of the Welland Canal is the rate of introduction of maximum-sized vessels into the system.

Another aspect of the capacity problem concerns the fact that the demand for service is often out-of-phase with the degree of service available. The Seaway is grossly under-utilized during the summer months when conditions, including weather, are at their best for the easy movement of vessels. On the other hand, at the opening and closing of the navigation season when conditions are at their worst, the Seaway is called upon to deal with heavy traffic flows. A smoothing out of the traffic flows would be of benefit to all.

To provide safe, efficient and economical service on the Seaway, modern traffic control centres schedule transits, disseminate vessel location information, provide weather data, supply information to schedule pilots, initiate action in the case of accidents and, in general, monitor the operation of the system. An extremely important element in maintaining an optimum level of service is an ongoing dialogue with the principal users of the system. A consultative mechanism has been set up to permit discussion between the Authority and various key elements of industry who use the waterway. Also, the Authority has entered into a joint program with the U.S. Saint Lawrence Seaway Development Corporation, the U.S. Coast Guard and the Canadian Coast

Guard to develop a reliable and acceptable all-weather navigation aid system. This system is expected to generate an increase in Seaway capacity with resulting reductions in vessel transit times during those periods at the beginning and at the end of the shipping season when conventional lighted floating aids must be removed because of ice. Improvements in system safety, capacity and transit time during periods of low visibility are also being considered.

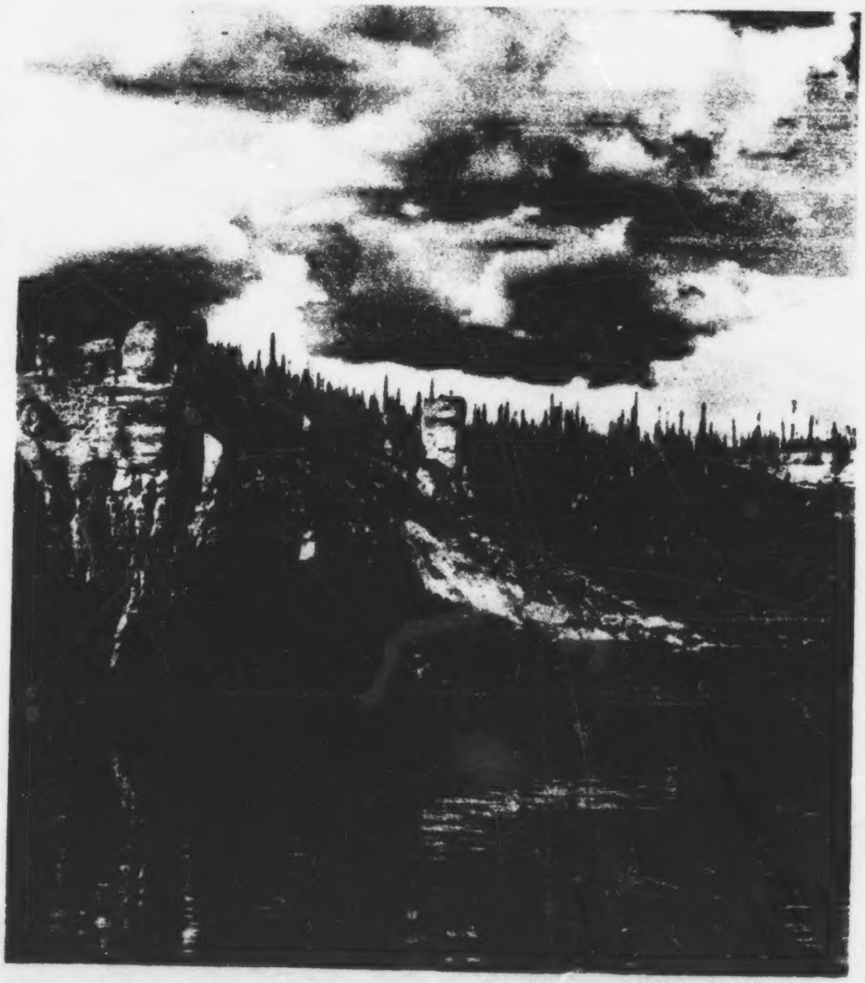
Northern Transportation

Northern Transportation Company Limited has provided marine transportation services throughout the Mackenzie River watershed since 1934 and along the Western Arctic Coast and islands since 1957. In 1975, operations were inaugurated to provide resupply services to five communities along the west coast of Hudson Bay, and to Coral Harbour on Southampton Island, using Churchill, Manitoba, as the base.

The Company transported a total of 303 000 tonnes of cargo in 1982, 89% of which was made in the Mackenzie-Arctic sector. Operationally, tonnage in 1982 was 13% below 1981 levels, but despite this drop in tonnage and the fact that the start of navigation on the Mackenzie River was delayed by close to two weeks due to later than normal break-up on Great Slave Lake, the navigation season was a successful one. The compensating factor was water levels which were satisfactory during 1982 in contrast to the lower levels of the previous several years.

Even though the Mackenzie River is the major transportation artery to the western Arctic, it remains an unimproved waterway. In its 1982 Annual Report, the company pointed to the need for a comprehensive dredging program as a means of ensuring the continuing viability of marine transportation services to the communities along the river, the Arctic coast, and to the expanding exploration market in the Beaufort Sea. But the lead time required for an undertaking of this magnitude is such that benefits would not accrue for several years. Although such a major program is not contemplated at present, consideration is being given to dredging a passageway through a limestone ridge that straddles the Mackenzie River at the "Ramparts". Removal of this obstacle will permit operation during periods of low water with a greater degree of safety than at present.

A limestone ridge that straddles the Mackenzie River at the "Ramparts" poses a threat to navigation during low water periods.



Wildlife

Waterfowl hunting is a sport that enjoys a high degree of popularity throughout Canada.

Besides the large number of Canadians who derive pleasure from observing wildlife, there are many others with different but equally gratifying pursuits. To those with cameras, wildlife affords the challenge and satisfaction of recording a wilderness experience for all time. To hunters, wildlife means sporting opportunities and, in many instances, food. Although the use of wildlife as a primary source of food has declined over the years, subsistence hunting, particularly in remote areas of the country, is still a way of life to the indigenous people there.

It is impossible to accurately determine the number of persons who photograph or simply observe wildlife. In the case of hunters, however, licences and permits help to give some indication of the numbers who take part as well as the value placed on this pastime. For example, over 2 259 000 licences to hunt big and small game were issued in Canada during 1978, returning almost $20 million to the provinces and territories under whose authority they were issued. In the same year, 525 000 Migratory Game Bird Hunting Permits were issued, with a value of $1.8 million to the federal treasury. Thus, to buy licences, hunters spent $21.8 million, and this was just a minor portion of their financial outlay. Their total expenditures on equipment, transportation, food and accommodation added untold amounts to their spending which, in turn, has been of major importance to local economies. Some indications of the level of spending by waterfowl hunters is given later in this section.

Many wildlife species live in or on the water and require it throughout most of their life. Other species use water less directly than as a primary habitat; nonetheless, water is essential to their well-being. In keeping with the nature of this publication, this discussion will deal largely with waterfowl and aquatic freshwater mammals.

Waterfowl: Waterfowl require water and water-vegetation complexes for nesting, brooding, resting, sanctuary and feeding. Most waterfowl nest near open water so that the young may reach it with ease after hatching and be near a source of food. Many nests are immediately adjacent to water or within a few hundred feet. Adequate vegetation is required along watercourses, and should extend a considerable distance back from the shore. Vegetation may be cattails and bulrushes, grass, sedge and alders adjacent to the shore and any number of combinations of tree species extending away from the shoreline, preferably in early to mid-successional stages of growth.

After hatching, the feeding young of waterfowl must be protected by vegetation. Most young ducks can survive only if the brood area provides both food and cover. The habitat must be productive of plant and animal life in many forms. For the young duckling, an abundance of aquatic insects and insect larvae is required, while both vegetable and animal matter must be present for adult birds.

During migration a large number of waterfowl must have extensive areas of open water which provide undisturbed conditions for resting and feeding. The Maritimes, and also the Peace-Athabasca Delta, provide extensive littoral areas, allowing the resting birds to enter shallow water to feed and then to move back to deeper water.

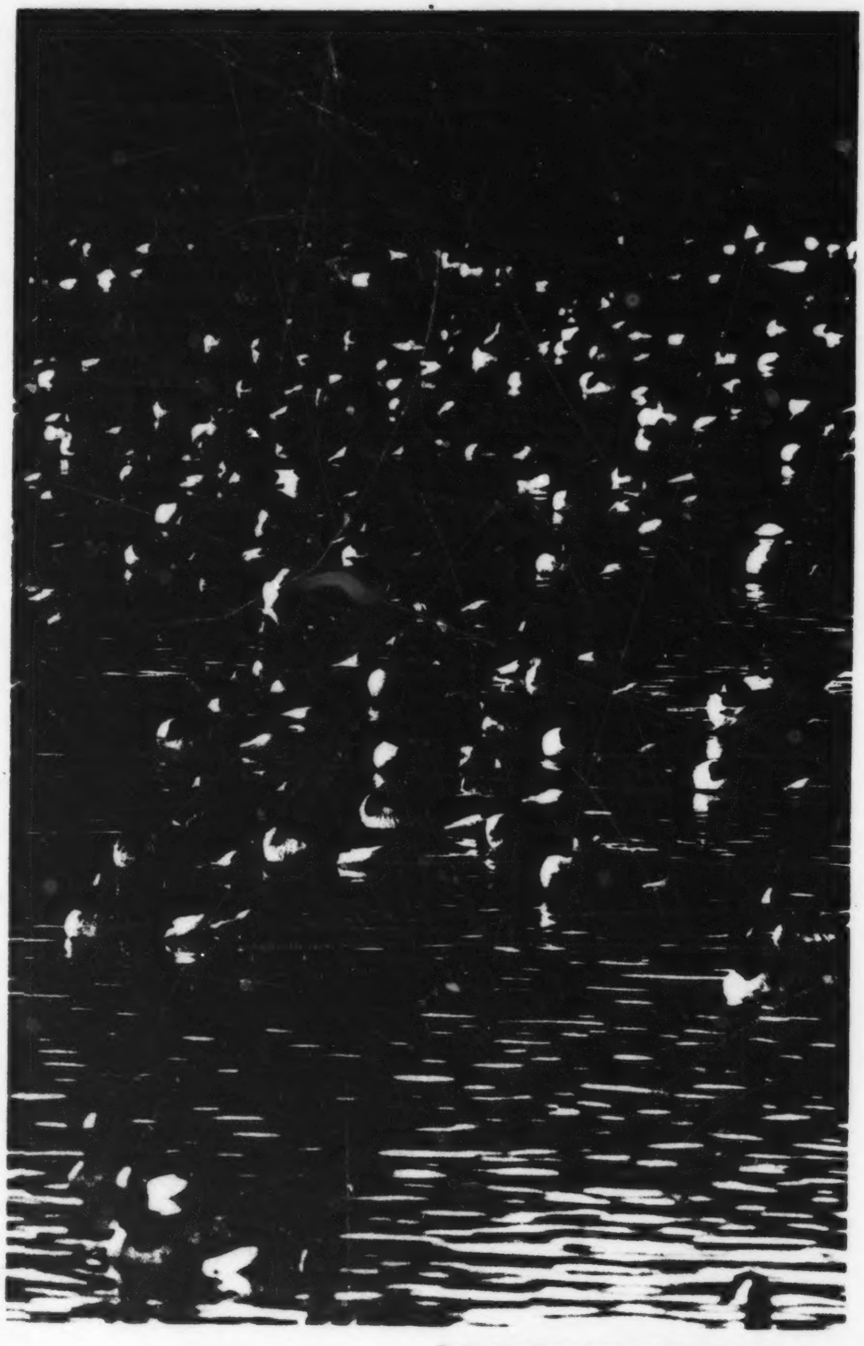
A sanctuary vegetation along the shoreline is necessary both for preflight juveniles and, during moulting, for flightless adults. From hatching until mid to late summer, young of the year ducks are incapable of sustained flight. For these, the presence of emergent vegetation in the form of sedges, grasses, and rushes is a necessity for survival. Similar conditions hold for moulting adults, which undergo wing and tailfeather changes. Flight during this period is difficult or impossible. Marshes, lakes and ponds providing a good interspersion of water and vegetation are required to shelter all birds unable to fly for great distances.

Freshwater Mammals: Principal aquatic and semi-aquatic freshwater mammal species are the beaver, muskrat, otter, and mink. Such species are adapted to an existence in or near water, making their dens or nests adjacent to the water, and using water for feeding, food storage and travel. Semi-aquatic species are less dependent on an aquatic environment, spending less time in water, but using water areas for a large proportion of their feeding and movement. Water needs for the various species within these two groups vary somewhat.

The beaver establishes its lodge on the water. Before doing so, however, certain conditions must be met. Considerable open water should be available, and frequent marshes and beaver food species must also be available. In lakes, a far more extensive water area and shoreline are required, for the beaver does not tolerate crowding, or he moves on. Good densities of beaver occur in areas with numerous small streams of low to medium gradients throughout productive forest lands producing the favoured beaver foods such as trembling aspen, large toothed aspen, willow, and some aquatic plants.

The otter travels in lakes and streams of any size, but prefers a series of lakes, ponds and dead waters connected by streams or rivers. Aquatic insect larvae, amphibians, fish and freshwater clams and snails provide their food. Special factors which must be present are grassy rubbing areas and banks which may be used as slides. Otter will tolerate a degree of salinity and are often found along sea shores where they feed on shellfish.

The muskrat is also adapted to an aquatic environment and, like beaver and otter, possesses webbed feet, muscular tails used in



During migration a large number of waterfowl must have extensive areas of open water which provide undisturbed conditions for resting and feeding.

swimming, and minute ear openings and nasal valves which close under external water pressure. Muskrat prefer a high degree of water-vegetation interspersion and inhabit areas similar to those used by some species of ducks. Aquatic grasses, sedges, blooms, and fruits are eaten by the herbivorous muskrat, but it will also eat a number of domestic root and tuber vegetables.

The mink, too, is a water-loving species, seldom living very far from lakes, streams, marshes or the seashore. Den sites are selected in a wide variety of situations including burrows in stream banks, abandoned muskrat or beaver houses, rock crevices, and cavities in stumps, logs or standing trees. An excellent swimmer, the mink is capable of seeking its food on land or by water, and may therefore be classed as semi-aquatic. The mink can dive to depths of five metres and can swim underwater for distances of up to 30 metres. Small aquatic animals such as frogs, fish, cray-fish and other invertebrates, snakes, birds, and small mammals make up their chief diet.

Fur Trapping and Production

The relative importance of the fur industry in the Canadian economy has fluctuated widely through the years but fur trapping continues to contribute substantially to the national income. As the country was being opened up and settled, wildlife habitat was reduced by the cutting and burning of forests, pollution of streams, industrial and urban development, drainage of wetlands, building of dams and other changes to the land and water environment. Despite these occurrences and the consequent exhaustion of much of the fur resources in the settled areas, the belt of northern Canada extending across the Yukon and Northwest Territories, the northern part of the Prairie Provinces, through northern Ontario and Quebec and into the Atlantic Provinces is one of the world's few remaining reserves of fine furs. In all these important trapping areas, the numbers of wild fur bearers are being well maintained through conservation measures – including the protection of rare or endangered species by limiting the harvest, by initiating a closed season for a time, and by establishing game preserves.

Today, as in the past, the value of wild fur production fluctuates considerably from year to year. This fluctuation is due to variations in the market price for pelts and the number of pelts taken. In 1981-82, the number of wild fur produced in Canada totalled 3.0 million, about the same as the quantity taken a decade ago, but well down from the 7.9 million in 1951-52.

The Fur Industry and the Economy

The market value of furs produced from wildlife in Canada during the 1981-82 season exceeded $58 million, a reduction from the higher values of the previous three seasons, but still a threefold increase from the values a decade ago. The most sought after pelts with the highest market values were lynx ($11.4 million), beaver ($8.5 million), fox ($7.2 million), muskrat ($6.5 million), marten ($5.8 million) and raccoon ($5.3 million). Table 35 shows the value of wild furs for aquatic and semi-aquatic species; it is evident that this group represents about one-third of the value of all wild furs for 1981-82.

In 1981-82, the number of wild fur taken in Canada totalled 3.0 million, about the same as the quantity taken a decade ago, but well down from the 7.9 million in 1951-52.

Table 35

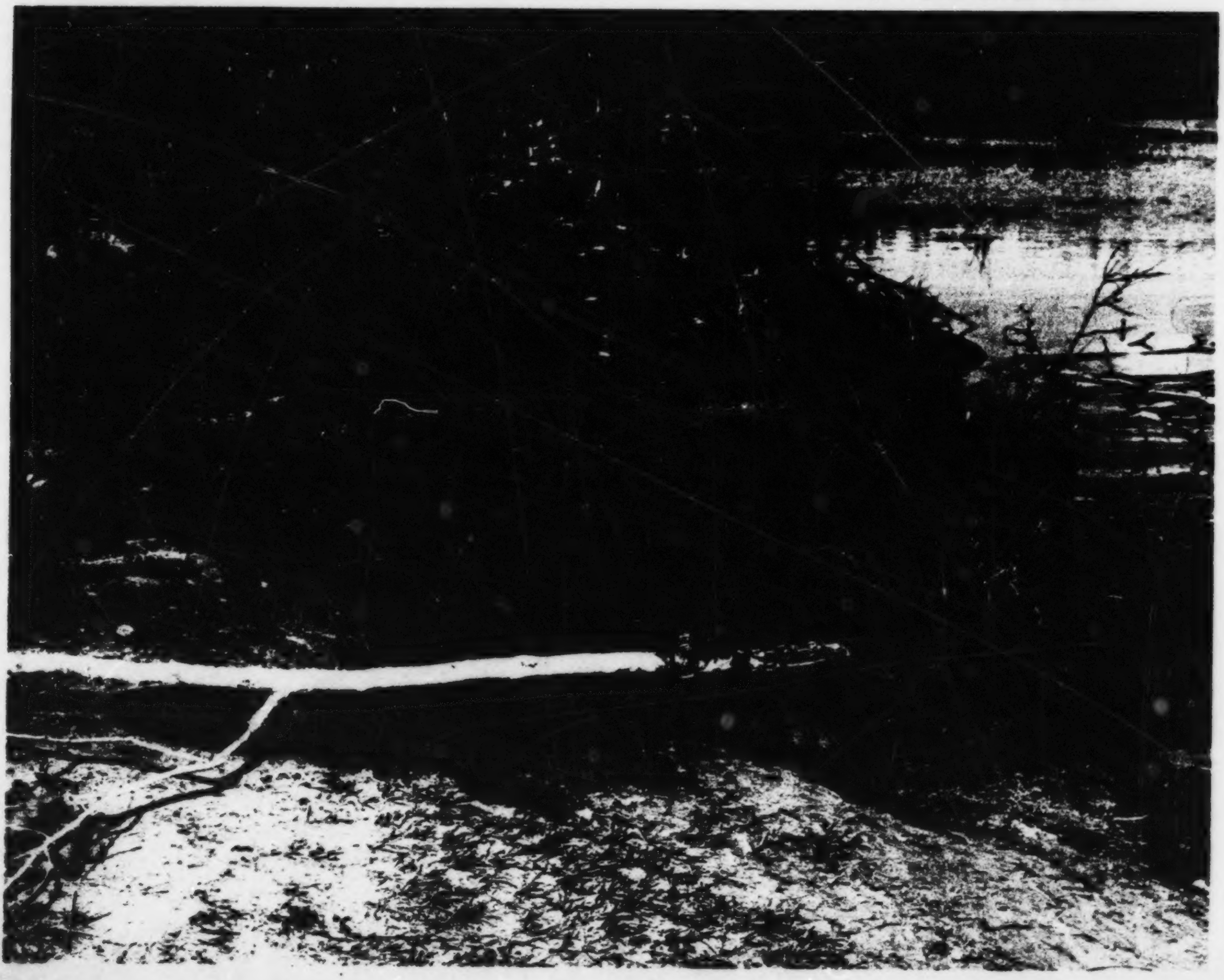
Quantity and Value of Pelts of Selected Aquatic and Semi-aquatic Wildlife Trapped in Canada 1981-82

	Quantity	Value
Beaver	382 893	8 531 693
Muskrat	1 526 086	6 506 473
Otter	19 643	1 049 958
Mink	105 117	3 029 079
	2 033 739	**19 117 203**

Source: Statistics Canada.

Migratory Birds

The Constitution Act of 1867 placed Canada's natural resources under provincial jurisdiction. As a result, wild creatures have belonged to, and have been managed by, the provinces in which they are found. In the early 1900s, however, the federal government became involved when a sharp decline in migratory birds became evident. Because most migratory birds nest in Canada but over-winter in the United States, the decline had international implications. Federal negotiations with the United States followed, culminating in the signing of the Migratory Birds Treaty in 1916. The Treaty, together with a resulting



The beaver, which establishes its lodge on the water, is truly an aquatic freshwater mammal.

Migratory Birds Convention Act passed by Parliament in 1917, created a federal responsibility for the management and protection of migratory birds. Since then, joint federal-provincial responsibility for managing migratory birds has produced close and continued cooperation and is resulting in a far reaching program directed towards first establishing and then attaining the goals of wildlife management.

For many years, migratory bird managers have had a major need for data relating to hunting in Canada. In a policy statement in the House of Commons in 1966, the Minister responsible stated "The use of waterfowl by hunters should be measured so that there can be an annual balancing of population gains and losses." A permit system and related surveys instituted in 1966 are providing such information on both a provincial and national basis, and are contributing substantially to a continental pool of data as well.

The key to the Canadian survey is the Migratory Game Bird Hunting Permit, issued for a nominal fee. Hunters so registered can be surveyed for information, especially about the number and species of birds killed. One survey, the National Harvest Survey, requests selected permit holders to complete a questionnaire on their hunting activities and success, and on the species taken other than ducks and geese. The Species Composition Survey asks others to return duck wings and goose tail fans in special envelopes, so that the species and the age and sex composition of the kill can be determined. The two surveys together provide a great deal of information about the hunters' harvest.

The permit system has made possible the estimates given in Tables 36 and 37 related to hunting of migratory birds in Canada. From Table 36, it is evident that waterfowl make up the major portion of migratory bird kills (95% in 1983). On the average, each waterfowl hunter spent about eight days hunting in 1983 and bagged about 11 birds. In the same year, those hunting migratory game birds other than waterfowl each averaged 6.4 days hunting and bagged three birds. Table 37, for 1972-1980, reveals that Canadians hunting within their own province constituted some 91.4% of all waterfowl hunters, with the remainder consisting of Canadians from out-of-province (4.3%) and U.S. visitors (4.3%).

Table 36

Statistics Related to Hunting Migratory Birds in Canada – 1983

	Waterfowl (ducks and geese)				Non-Waterfowl*		
	Number of Hunting Permits Sold	Active Hunters	Retrieved Kills	Recreation Days	Active Hunters	Retrieved Kills	Recreation Days
Newfoundland	30 977	21 047	133 160	258 907	6 176	15 237	60 981
Prince Edward Island	5 898	5 438	51 839	68 203	813	913	6 601
Nova Scotia	13 468	10 553	127 056	113 022	3 334	5 459	25 577
New Brunswick	12 758	8 807	80 418	59 328	2 244	8 776	16 991
Quebec	67 700	52 436	537 782	478 571	15 312	71 355	100 301
Ontario	139 569	103 800	961 113	797 467	21 716	67 397	128 719
Manitoba	40 443	33 362	442 999	239 030	3 189	3 095	14 910
Saskatchewan	45 383	38 482	591 885	263 097	4 704	5 801	23 260
Alberta	61 742	51 782	638 558	349 904	5 221	12 373	29 508
British Columbia	24 170	17 450	209 032	152 534	2 634	8 620	13 992
Northwest Territories	750	821	15 750	5 638	159	–	707
Yukon	474	262	3 334	1 877	56	–	387
Canada	**443 332**	**344 240**	**3 792 928**	**2 787 578**	**65 558**	**199 026**	**421 934**

*Non-waterfowl categories include the following: American Woodcock, Common Snipe, American Coot, Sandhill Crane, Mourning Dove and Band-tailed Pigeon.

Source: Canadian Wildlife Service Progress Note No. 154

From long-term records, the number of permits sold in a single year has increased from 380 000 in 1966 to a high of 525 000 in 1978. Since then, the number of hunting permits sold fell to 498 916 in 1980 and to 443 332 in 1983.

About 80% of North American waterfowl, consisting of three species of swans, five of geese, and twenty-nine of ducks, are bred in Canada. During a season their numbers fluctuate greatly. In May, there are about 46 million waterfowl in Canada; by September this number swells to 70 million as a result of increases from breeding, and by January the number dwindles to 1 1/4 million – which reflects the low point in terms of wintering population. Of the total waterfowl breeding here in spring, about 15% are swans and geese, and 85% are ducks – mostly mallards. On a national basis, the trend in the duck population has declined slightly over the past ten years, while Canada Geese have been on the increase.

On average, it is estimated that the annual harvest of ducks in Canada by permit holders is about 4 million. Another 1 million are harvested by Indian and Inuit hunters, and 1 million ducks die as a result of wounding or being shot illegally, bringing the total killed to 6 million. For geese, the sport kill is about 0.5 million and the total kill from all causes is slightly over 1 million. In comparison, about 20 million ducks and 3 million geese are accounted for in the United States (including crippling and illegal kills but not the harvest by Indian and Inuit people).

About 15% of the hunters responding to the National Harvest Survey reported taking migratory birds other than waterfowl. In this category, woodcocks were the most commonly hunted birds with estimated average annual kills in Canada of 116 000. Common snipe came next at 74 000, followed by coot at 25 000. Smaller numbers of sandhill cranes, mourning doves and band-tailed pigeons were also taken; cranes may be hunted only in Saskatchewan and Manitoba, and doves and pigeons only in British Columbia.

Waterfowl's Contribution to the Canadian Economy

In 1982, a study was undertaken by Environment Canada to examine the economic aspects of waterfowl. Specifically, the study was directed towards answering questions concerning the dollar value of waterfowl to users and the costs incurred in utilizing and preserving the resource. Only tangible values were evaluated; intangibles, such as the benefits from recollection of recreational experiences, were not considered. The results of the study are given in Table 38 and discussed briefly in following paragraphs.

Indian and Inuit settlements in the Hudson Bay area depend upon waterfowl as a meat and egg food source to a substantial degree. Those located in other areas of the North also depend upon waterfowl for food, but to a lesser extent. The total expenditure by Indian and Inuit people in proxy dollar terms was estimated to be $5.1 million annually in 1980.

The estimated expenditure by active resident hunters in 1980 to gain access to waterfowl was $85.2 million. The additional expenditure on durable items such as recreational vehicles, special clothing, decoys, guns, etc., was a further $69.5 million, bringing the annual outfitting plus access expenditure to $154.7 million. The cost of hunting permits and licences pro-rated so as to apply only to waterfowl was $3.1 million. This brought annual outfitting plus access and licence expenditures to a total of $157.8 million for the year 1980.

The expenditures made in Canada in 1980 by some 17 000 active non-resident hunters was $5.3 million made up of an estimated $4.6 million for travel, lodging, etc., and $0.7 million for licences.

Survey results also show that about 2 million adults engaged in bird watching. Out of this total less than one-third concentrated wholly or mainly on waterfowl. On the average, it is estimated that about 5 million recreation days and $62.4 million were spent during 1980 accessing waterfowl for bird watching and bird photography purposes.

Table 37

Origins of Waterfowl Hunters in Canada 1972-1980

	Canadians		U.S. Visitors	
	Residents	Out-of-Province		Total
Eastern Canada totals	196 149	6 234	8 215	210 598
%	93.1	3.0	3.9	100.0
Western Canada totals	153 743	10 372	8 099	172 214
%	89.3	6.0	4.7	100.0
Canada totals	349 892	16 606	16 314	382 812
%	91.4	4.3	4.3	100.0

The quantities represent the average annual number of hunters over the nine years.

Source: Canadian Wildlife Service Progress Note No. 130

Ducks Unlimited, a private U.S.-Canadian organization, has worked cooperatively with provincial and federal agencies in Canada to restore, develop and preserve habitat for waterfowl. In 1980, United States funding spent in Canada by Ducks Unlimited reached $18.5 million. This reflects the fact that the U.S. hunting community is prepared to share in the cost of wetland conservation in order to maintain Canadian breeding conditions for birds that may accrue to U.S. hunters. As noted earlier, U.S. hunters reap a much greater harvest of these waterfowl than do Canadians.

Conservation and management costs to the federal government, including law enforcement by the R.C.M.P., amounted to $7.3 million in 1980. Parallel costs for the provinces amounted to about $5.0 million. Compensation payments to farmers for crop losses due to waterfowl amounted to $2.1 million, and an additional $1 million was spent on a waterfowl related damage prevention program. In total, therefore, about $15.4 million annually was spent by governments on waterfowl management in 1980.

Loss of farm revenue attributable to grain consumption and crop trampling by waterfowl is estimated to be about $10 million annually. As already indicated, farmers are reimbursed by government (federally/provincially cost shared) for approximately $2.1 million of this amount, but this leaves them with an uncompensated annual rearing cost of approximately $7.9 million.

Damage to aircraft resulting from striking waterfowl, plus the cost incurred in undertaking measures to avert such damage, amounted to about $1.6 million in 1980.

From the foregoing, it is evident that there are positive and negative aspects to maintaining the waterfowl of Canada but it is equally obvious that waterfowl related activities in Canada are important to both Canadian outdoorsmen and Canada's economy.

Wetlands and Wildlife

Historically, the general perception of wetlands has been one of watershed or unproductive areas because common activities like agriculture, building or land-style transportation were difficult in wet areas. Thus, it is not surprising that vast areas of wetlands have been reclaimed, usually by drainage, to permit other uses, particularly the rich soil complex of marshes and flat gradients so attractive to agriculture. Near urban areas, pressure to reclaim wetlands also arises in the form of demands for industrial and residential space, disposal sites and waterfront transportation facilities. The conversion of Canadian wetlands in many areas has been extensive. Naturalists, ecologists and the public are concerned about this trend for a number of reasons.

Table 38

Expenditures Associated With Waterfowl Related Activities in Canada – 1980

millions of dollars

	Expenditure By Purpose		Total
Indian and Inuit Hunters	To procure food	5.1	5.1
Resident Sport Hunters	Access	85.2	
	Capital items	69.5	
	Licences	3.1	157.8
Non-Resident Sport Hunters	Access	4.6	
	Licences	0.7	5.3
Bird Watchers	Access and Capital Items	62.4	62.4
Ducks Unlimited	Restore and Preserve Habitat	18.5	18.5
Governments	Conservation and Management	12.3	
	Compensation to Farmers	2.1	
	Damage Prevention	1.0	15.4
Farmers	Waterfowl Damage	10.0	
	Compensation for Damage	−2.1	7.9
Airlines	Direct Damage	.9	
	Damage Prevention	.7	1.6
			274.0

Source: Internal Environment Canada Study

Loss of farm revenue attributable to grain consumption and crop trampling by waterfowl is estimated to be about $10 million annually.

Wetlands act like giant sponges, soaking up rain and snowmelt and slowly releasing water in drier seasons. Thus, they help to reduce floods and ease the worst effects of drought. Draining ponds, sloughs and marshes often lowers the water table and dries up wells. Wetlands also reduce soil erosion by checking or slowing the runoff from storms and thaws.

Wetlands reduce pollution by filtering the waters running off to lakes, rivers and streams. The vegetation in wetlands removes phosphates and other plant nutrients washed in from the surrounding soil, thereby retarding the growth of algae. This growth is a serious problem in some of Canada's major waterways where dead and decaying organic matter rob the deeper waters of their oxygen.

Wetlands rank among the most productive ecosystems in the world. Compared to the average productivity of lakes and streams (500gm/m^2/yr) and farmland (650gm/m^2/yr), wetlands can produce as much as 2000gm/m^2/yr of plant matter. The abundance of plant matter, common on wetlands, supports a wide variety of wildlife by providing ideal feeding, rearing and breeding grounds. Wetlands are important to local populations as well as seasonal visitors such as migratory birds and spawning fish. The fact that wetlands nourish smaller mammals such as the beaver and muskrat is important to Canada's fur industry, but wetlands are especially a boon to birds. More than 100 species of birds inhabit or make use of Canada's marshes, swamps or sloughs. Some, like the swamp sparrow and marsh wren, nest there almost exclusively. Many millions of ducks, geese, gulls and other waterfowl also nest, breed and feed in wetlands, along with numerous waders and shorebirds.

The natural, reversible changes in wetlands may be almost insignificant compared to the disruption caused by human interference. Dredging a pond can make it unsuitable for birds that require shallow water. Draining or filling in wetlands permanently destroys entire communities of plants and wildlife. Burning off or cutting down surrounding weeds, brush or other vegetation eliminates at least temporarily, vital nesting places and escape cover. Building a highway through a coastal marsh or erecting a dock at the marshy edge of a lake can also be damaging.

This destruction is happening all across the country, as industry, commerce and agriculture continue to drain existing wetlands. A report by the Federation of Ontario Naturalists states that agricultural, urban and recreational development have reduced Southern Ontario's original stock of 2.3 million hectares of wetlands to its present 0.3 million hectares. On the prairies, further millions of hectares have been drained and put to the plow, not only destroying wildlife habitat, but also frequently lowering the water table. The trend to transforming wetlands continues unabated with the result that it has become an issue of considerable importance.

Wetlands on Canadian Farms

Wetlands can be and have been used by farmers for multiple purposes. They can be valuable for producing hay, for raising domestic waterfowl, and for providing sources of water for livestock and other purposes. Farmers in some localities have "dug-outs" made to store water, and some of these have even proven suitable for raising trout (aquaculture). But this is only one side of the story.

To many farmers, retention of wetlands can be expensive. It takes longer, and costs more, to plant and harvest crops in irregular patterns around sloughs and pot-holes. Machinery often becomes mired in the mud resulting in costly "down-time". Moreover, migrating waterfowl attracted to the wetlands habitat may consume and trample the farmers' nearby crops, reducing yields.

Crop production decisions based on price indications are normally made with the intention of maximizing returns to the landowner. The problem that arises in the case of wetlands is that while certain uses, such as for migratory waterfowl, may be regarded as a "crop" from wetlands, it is a crop which the private wetland owner derives few of the benefits. This particular use of the wetlands, therefore, is not financially rewarding to him and will not be attractive to him unless he can put the wetlands to some other remunerative use.

A contentious issue is that the social benefits of wetlands for such uses as waterfowl production accrue primarily to hunters, while the costs of maintaining the nesting habitat of a large portion of waterfowl is borne by farmers. Compounding the problem is the fact that the habitat area is not a single privately or publicly held area but one composed of many private holdings scattered over 100 million acres. This is not only where five out of eight ducks shot by hunters in North America are raised, but also the source of 98% of wheat production in Canada. As the world demand for cereal grains increases, there will be more pressure on farmers to increase grain crops, an objective which will not favour retention of sloughs or pot-holes in the middle of grain fields.

Waterfowl Sanctuaries Protect Wetlands

Canada's earliest effort in wetland's protection dates back to 1887. In that year, a refuge for the protection of waterfowl was established in Saskatchewan at Last Mountain Lake, the oldest refuge in the Western Hemisphere.

Following the signing of the Migratory Birds Treaty with the United States, legislation was passed to provide protection for migratory birds and their habitat. In 1919, the first Migratory Bird Sanctuary was established at Bonaventure Island, Quebec. Today, 62 sanctuaries covering an area of 4125 km^2 have been established south of 60°N latitude with the cooperation of the provinces and private citizens. In the North, there are 14 sanctuaries established on Crown Land occupying 110 800 km^2.

In 1973, the Canada Wildlife Act was passed to further strengthen Canada's ability to protect essential migratory bird habitat. Using that legislation, the Canadian Wildlife Service has purchased about 500 km^2 of key habitat in Southern Canada.

The Convention of Wetlands of International Importance

In 1981 Canada acceded to the Convention of Wetlands of International Importance. To date 15 areas have been dedicated to the List of Wetlands of International Importance. Although the Convention does not have any legislative base for providing protection, international recognition provides a deterrent to development that might degrade the areas' importance to wildlife. The 15 areas cover 106 500 km^2 and have been dedicated through the cooperation of the provinces, territories, Parks Canada, and the Department of Indian Affairs and Northern Development.

Canada's Fisheries

Bounded by three oceans and blessed with thousands of freshwater lakes and rivers, Canada has always been rich in fisheries resources. This natural abundance first lured Europeans to its shores. But Canada has been a fishing nation for much longer than the 400 years of European settlement. Thousands of years before European immigration, our waters gave sustenance to those who lived here. Even today, native people continue to exploit the fisheries as an essential part of their livelihood.

Today, Canada's fisheries support a multimillion dollar commercial industry which employs more than 100,000 Canadians, either as fishermen or in the fish processing industry. Thousands more depend on the fisheries for their livelihood, including those employed in vessel design and construction, equipment manufacture and supply, and wholesale and retail operations.

The fisheries also provide some of the most spectacular sportfishing in the world. Six million Canadian and foreign anglers spend and invest over $1.7 billion every year on goods and services directly related to sportfishing. These expenditures also support thousands of jobs in Canada's economy.

1. The Resource

Canada's fishing grounds fall naturally into four main divisions: the Atlantic, Pacific, and Arctic ocean fisheries, and the inland freshwater fisheries.

The Atlantic Ocean Fisheries

The fisheries off the coasts of Newfoundland, Nova Scotia, New Brunswick, Prince Edward Island and Quebec are the oldest of the Canadian commercial fisheries. The fisheries in these waters account for more than two thirds of the marketed value of all Canadian commercially-caught fish. The main species are: groundfish (especially cod, but also haddock, pollock, hake, cusk, redfish, catfish, and a wide variety of flatfish); shellfish (principally lobsters, as well as clams, scallops, oysters, shrimp and crab); and pelagic fish (herring, mackerel, smelts, tuna and Atlantic salmon).

Sport fishing activity also takes place in Atlantic ocean waters, although to a much lesser extent. Anglers fish primarily for mackerel, cod, pollock and the famous bluefin tuna.

Canada's Atlantic and Pacific coasts are among the world's most prolific fishing grounds. (Port of Prince Rupert, B.C.)

The Pacific Ocean Fisheries

The commercial fisheries of coastal British Columbia are newer. They account for about one quarter of the landed value of all commercially-caught Canadian fish. Species caught in order of importance are salmon, herring, halibut and other flatfish, and lingcod, black cod, albacore, tuna, clams, crabs, and oysters.

In Pacific coastal waters, anglers fish mainly for chinook, coho and pink salmon as well as the steelhead, a sea-going rainbow trout. Anglers also fish for halibut and other flatfish.

The Arctic Ocean Fisheries

Canada's largest coastline is in the Arctic, an area that offers a wide variety of aquatic marine life. Commercial fisheries potential is limited, however, and will likely be confined to inshore fish stocks often associated with major river systems such as the Mackenzie. There is a potential commercial herring fishery in the Liverpool Bay area to the east of Inuvik. Also, the Department of Fisheries and Oceans has a feasibility study currently underway to look at a potential shrimp fishery in the Hudson Strait and Ungava Bay. Localized fisheries for arctic cod in the same area and along the Labrador coast are also possibilities.

A popular and growing non-consumptive use of fish resources is the recreational pursuit of watching concentrations of narwal and beluga whales in areas such as Churchill, the Mackenzie delta, Bylot Island and in many communities such as Pond Inlet, Arctic Bay and Grise Fiord.

The Freshwater Fisheries

Canada's inland waters make up almost one quarter of the world's freshwater area and nine percent of the total flow. These lakes and rivers provide a basis for several important commercial fisheries. A great variety of fish are taken in these inland lakes: yellow pickerel (or doré) in all provinces west of Quebec; whitefish in the same areas; perch mostly from Ontario and Quebec; and varieties of trout, particularly rainbow and lake trout.

Species with considerable local importance include: alewife in New Brunswick; eels in Quebec; smelt and tullibee in Ontario; pike in Alberta and Saskatchewan; sauger in Manitoba; and arctic char in the Northwest Territories.

Over 90 percent of all sportfishing in Canada takes place in freshwater and anglers pursue about 50 species of fish. Most frequently caught species are smelt, trout, perch, walleye (pickerel), pike and bass.

2. The Users

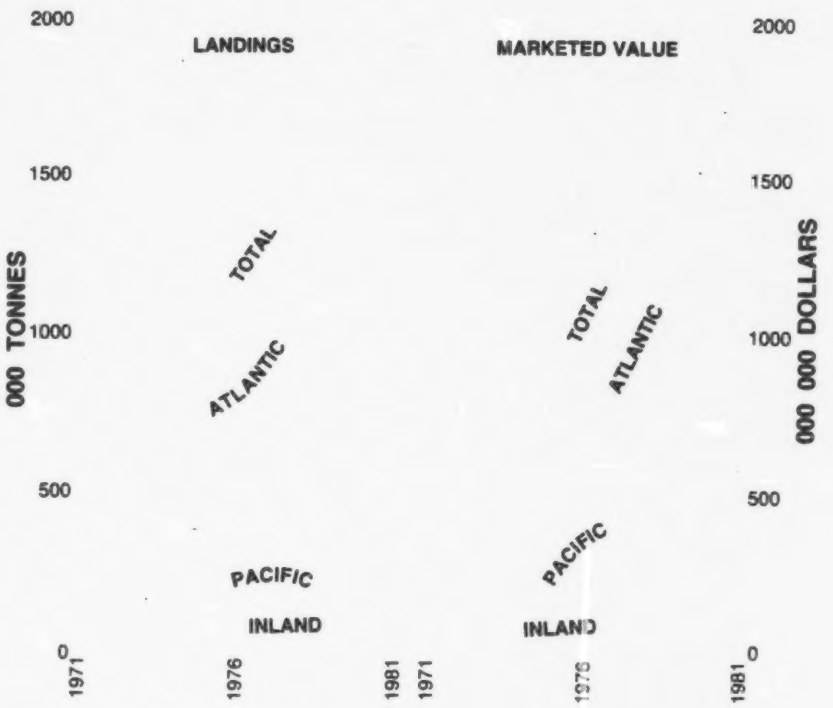
The Commercial Fisheries

In volume and value, Canada's commercial fisheries rank among those of the top 12 fishing nations. Canada sells 80% of its catch in foreign markets and is, in dollar

In 1981, the Atlantic fishing accounted for almost 85% of all fish landed in Canada, and about 67% of the marketed value. (Dead Man's Bay, Newfoundland) terms, the number one exporter of fish in the world.

Figure 1

Quantity and Value of Sea and Inland Fish Landed in Canada 1971-1981



Source: Canada Department of Fisheries and Oceans

Figure 1 illustrates the trend in total landings and values for all Canadian commercial fisheries since 1971. Between 1971 and 1981, annual landings fluctuated between 969 000 tonnes (1974) and 1 442 000 tonnes (1979) while marketed value grew from $462 million (1971) to $1914 million (1981). Although the rise in total landings over the decade has not been large, the growing value of the marketed product has resulted in a four-fold increase in total marketed value.

In 1981, the coastal and freshwater fisheries provided slightly more than 1.4 million tonnes of fish products with a marketed value exceeding $1.9 billion (Table 39). The Atlantic fishery made by far the greatest contribution, accounting for 83.7% of all commercial fish landed in Canada, 66.0% of landed value and 66.8% of the total Canadian marketed value. These and the corresponding statistics for Pacific and Inland fisheries are given in Table 39.

The marketed values in Table 39 represent improvements in all sectors when compared with 1980. In 1981, the marketed value of production rose 30% over 1980 values on the Pacific coast, 10% on the Atlantic coast, and slightly more than 20% for freshwater fisheries. The marketed value of Canadian exports of fishery products exceeded $1500 million (in 1981), a 19% increase over the 1980 value. Improvements were seen in almost all categories. The United States remained the most important market for Canadian fishery products, followed by the European Community and Japan.

Canada also is an importer of fish products and in 1981 imported a total of $372 million worth. The United States was the major

Table 39

Relative Contributions of Coastal and Inland Fisheries – 1981

	Landed Quantity		Landed Value		Marketed Value	
	(000 tonnes)	(%)	($000,000)	(%)	($000,000)	(%)
Atlantic	1194.6	83.7	568.1	66.0	1277.6	66.8
Inland	49.9	3.5	57.1	6.6	108.3	5.7
Pacific	183.1	12.8	236.2	27.4	526.9	27.5
Total	1427.6	100	861.4	100	1912.8	100

Source: Canada Department of Fisheries and Oceans supplier.

Provincial Highlights

Table 40 shows for 1981 the quantities and values of sea and freshwater fish landings by province.

Despite the fact that it accounted for only 13% of landings in 1981, the Pacific fishery contributed a marketed value of $526.9 million or 27% of the total Canadian marketed value for all species. It was this value, made up largely of the annual Pacific salmon catch, that gave British Columbia a higher financial return than any other province in 1981. Newfoundland had the largest landings during the year, while Nova Scotia had the largest landed value.

Quantity and Value of Individual Species

Table 41 illustrates the changes between 1971 and 1981 in landings and marketed value for all fish species which had a marketed value of at least $15 million in 1981.

Table 40

Quantity and Value of Sea and Freshwater Fish Landings, by Province – 1981

	Landings ('000 tonnes)	Landed Values ($000,000)	Marketed Values ($000,000)
British Columbia	183.1	236.2	526.9
Nova Scotia	467.5	264.1	484.2
Newfoundland	498.7	170.8	457.8
New Brunswick	103.6	55.0	240.3
Quebec	88.3	48.2	85.9
Ontario	28.1	31.8	63.5
Prince Edward Island	38.5	31.8	55.4
Other Provinces and Territories	19.8	23.5	42.9
Canada	**1427.6**	**861.4**	**1912.8**

Source: Canada Department of Fisheries and Oceans.

Of all fish species, cod registered the largest increase in landings between 1971 and 1981.

On the whole, the total landings from 1971 to 1981 underwent a relatively small increase, from 1 249 623 tonnes in 1971 to 1 427 650 tonnes in 1981, or 14.2%. However, the mix and match of the various species underwent a significant change, with herring, flounders,and sole, redfish, halibut and perch registering declines, and all other species showing increases. Significant increases of 20 000 tonnes or greater were reported for cod, scallops, crab, haddock, pollock, capelin and salmon. Cod landings, which rose from 248 214 tonnes in 1971 to 446 100 tonnes in 1981, registered by far the largest increase in landed quantity.

Cod also showed the largest increase in marketed value when that value increased more than $300 million over the decade. Similarly, the marketed value of the salmon increased by $282 million despite a much smaller growth in landings. Altogether, the total marketed values for 1981 increased more than three-fold over the values for 1971 and, despite the declines in some landings, the 1981 marketed value for each species was larger than its corresponding 1971 value.

In 1981, Canada's commercial fisheries experienced a good year with marketed value exceeding any earlier year on record. Landed quality and landed value were near record highs, exceeded only by higher values in 1979.

In 1981, the fisheries industry provided some 106 000 jobs and more than one billion dollars in value added. As such, one out of every 100 jobs, and roughly the same proportion of gross domestic product, was provided by the fisheries in Canada. In a breakdown of the employment total in 1981, some 70 700 sea fishermen and 8060 inland fishermen depended upon the fisheries for their livelihood. An additional 27 500 persons were employed in the 364 fish processing plants across Canada.

Although all regions of Canada gain from commercial fishing, the economic returns, and therefore the economic impacts, are greatest in those provinces sharing in the coastal fisheries. For example, in 1980, the fisheries provided Newfoundlanders with one in every five jobs and about 15% of the province's gross domestic product. Nova Scotia and Prince Edward Island too gained about 15% of their gross domestic product from the fisheries in 1980, but the contributions to the work force ranged from one in 20 for Nova Scotia, to one in 12 for Prince Edward Island. The Task Force on Atlantic Fisheries, in their report "Navigating Troubled Waters", stressed how dependent the Atlantic Provinces are on the fishing industry when they said, "The Atlantic fishery is a very people-oriented industry. It is a way of life that provides the lifeblood of thousands of individuals and hundreds of communities throughout the Atlantic Region." Other provinces may not depend upon the fisheries as greatly, but they nevertheless receive significant benefits from them.

Table 41

Landed Quantity and Marketed Value of Sea and Freshwater Fish Caught in 1971 and 1981

Species	1981		1971	
	Landed Quantity (thousand tonnes)	Marketed Value ($000,000)	Landed Quantity (thousand tonnes)	Marketed Value ($000,000)
Salmon	88.1	383.0	61.9	101.4
Cod	446.1	370.1	248.2	65.3
Herring	199.4	207.8	429.3	55.1
Lobster	21.7	125.6	17.3	49.7
Scallops	89.9	111.4	42.0	19.3
Crab	39.6	89.0	7.9	7.2
Flounders and Soles	109.9	88.4	133.1	33.6
Redfish	81.5	55.0	114.1	22.7
Haddock	57.0	44.9	29.2	10.0
Shrimp	17.2	40.8	2.1	3.4
Perch	5.0	29.5	7.3	7.9
Yellow Pickeral	6.2	29.2	2.9	3.9
Pollock	41.7	26.7	12.0	2.9
Turbot	28.8	25.8	10.4	2.7
Capelin	28.8	18.6	2.6	.1
Squid	18.3	16.8	1.6	.1
Whitefish	8.3	16.4	8.0	6.9
Halibut	5.2	15.7	17.5	13.3
Others*	141.9	218.1	102.2	56.3
Total	1 427.6	1 912.8	1 249.6	461.8

*Species having a marketed value of less than $15 million in 1981.

Source: Canada Department of Fisheries and Oceans.

The Recreational Fisheries

Canada's recreational fisheries also make an important contribution to the economic well-being of this country. Canada is not only the world's number one exporter of fish, it also attracts more foreign tourist anglers than any other nation.

Sportfishing is widely dispersed across Canada with most streams and lakes providing scope for this leisure-time activity. Many species taken commercially such as lake trout, salmon and pike are also popular with sport fishermen.

In 1980, well over six million persons of all ages "went fishing" in Canada. Of this number, about 5.2 million were resident Canadians and about one million were visiting anglers from other countries. In terms of overall participation, one out of five Canadians fished in 1980.

The foregoing sections on the commercial fisheries have produced statistics on landed quantity, landed value and marketed value as measures of the worth of commercial fishing. Since similar criteria for sportfishing are unavailable, sportfishing has been given an imputed value based on annual expenditures and investments in this pastime. As shown in Table 42, sportfishing generated $1761 million in expenditures and investments in 1980. About $1111 million of this amount was spent on food, lodging, travel costs, boat operations and fishing supplies. Just over $650 million was invested in boats, motors, special vehicles, cottages and land that was directly attributable to sportfishing. The million foreign anglers, mostly from the United States, accounted for about $300 million of the expenditures in Canada during 1980, and provided about 9% of Canada's total foreign exchange revenues from tourism. Excluded from these totals was a further $620 million invested in durables and property associated with water-related recreational pursuits other than sportfishing. Taken together, these figures reflect the importance of these activities to Canada's economy, and are indicative of the economic activity and the employment generated by sportfishing across Canada.

An aspect of sportfishing that is often overlooked is the sportfishery's contribution to Canada's food supply. Anglers estimated that they consumed some 45 200 tonnes of the fish they landed in 1980. With about 70% of the commercial catch exported, the sport catch is small compared to the combined total of Canada's commercial and sport catch. Nevertheless, the sport catch represented close to 40% of the total con-

Table 42

Actual Value of Commercial Fisheries and Imputed Value of Sportfishing in 1980

(millions of dollars)

Province/Territory	Commercial Fisheries Marketed Value	Sport Expenditures and Investments
Newfoundland	391	28
Nova Scotia	420	20
Prince Edward Island	52	3
New Brunswick	214	33
Quebec	82	236
Ontario	47	709
Manitoba	28	84
Saskatchewan	8	70
Alberta	2	155
British Columbia	404	408
Yukon & NWT	3	17
Total	1 651	1 763

Source: Canada Department of Fisheries and Oceans.

Fishing through the ice has become a popular pastime for both young and old in many parts of Canada.

sumption of domestic finfish caught by the sport and commercial fisheries in Canada in 1980.

The Native Fisheries

Canada's aboriginal peoples constitute the third major group using the fishery resource. Hunting and fishing have long been an integral part of the culture and tradition of native people.

The native fisheries are primarily food fisheries, although many natives, especially in British Columbia and the North, are commercial fishermen as well.

It is difficult to quantify the economic value of the native food fishery throughout Canada. However, fish resources make up approximately 20-30% of the diet of non-urban west coast natives, for example. The value of these resources if calculated from nutritional equivalents is in excess of $25 million. In addition, in the Arctic, exploitation of fish and marine mammals has been, and continues to be, a dominant activity for native residents who make up 59% of the population of the Yukon and the Northwest Territories.

Fish and marine mammal resources serve several functions in the social, cultural and economic life of northerners. While small on a comparative national basis, these resources are as important to local communities as the Atlantic fishery is to the communities of Newfoundland. The resources are harvested for domestic, recreational and commercial purposes. A conservative estimate of the Arctic resources in economic terms suggests the commercial and domestic fisheries to be worth $20 to $30 million annually in income and food. Approximately 75% of this relates to native fisheries.

3. Management of the Fisheries

The year 1977 was a critical one for Canada and many other coastal states. It saw the establishment of the 200 mile (329 kilometre) fishing zone which gives Canada exclusive jurisdiction over the fisheries within 200 nautical miles of its coasts. The extended zone allowed Canada to more effectively manage its marine resources, which, in some cases, had been seriously depleted.

The rebuilding of overfished stocks was Canada's first priority. In many cases, this meant setting strictly enforced limits on catches so that stocks would prosper and provide a long-term basis for a source of food and a viable industry.

The results of careful resource management have been dramatic. Depleted stocks of fish on the Atlantic coast have, for the most part, recovered, and as the populations increase, so do the catch limits. Landings of groundfish on the Atlantic coast have increased by 56 percent since 1977, and some stocks have more than doubled. Canada is also working with the United States to rebuild depleted stocks of Pacific salmon.

Since 1977, Canada has negotiated a variety of bilateral agreements with foreign countries to allow them to continue to fish within Canada's extended jurisdiction for stocks surplus to Canada's harvesting capacity, and to provide a smooth transition to the new regime of fisheries management off the Canadian coasts. Multilateral agreements which applied before 1977 were renegotiated to take into account the 200-mile limit. A new international organization was established to ensure recognition of Canada's special interest in the area beyond and immediately adjacent to the 200-mile limit on the Atlantic Coast. Agreements were also negotiated with the United States to provide for reciprocal fishing and third party settlement of the boundary between Canada and the U.S. fishing zones off the Atlantic Coast. Canada also recently signed a treaty with the United States for improved management of Pacific salmon.

Canada has achieved an international reputation in fisheries research and cooperates with many nations to exchange scientific data and to formulate policies for development and conservation of fisheries. Our country is represented on a dozen international fisheries bodies (including the Northwest Atlantic Fisheries Organization, the International Council for Exploration of the Sea, the International Commission for the Conservation of Atlantic Tunas and the International North Pacific Fisheries Commission).

Responsibility for fisheries management in Canada rests with the federal government through its Department of Fisheries and Oceans, an organization with roots formed more than 100 years ago. It administers programs in all regions of Canada to ensure the conservation, protection and expansion of fisheries resources.

Provincial governments, over the years, have been delegated certain administrative responsibilities for the freshwater fisheries within their boundaries which they exercise on behalf of the federal government. These responsibilities relate to licensing, access, leases, ownership and succession.

The federal government exclusively manages all ocean water fisheries and administers federal freshwater fisheries laws in Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, the Yukon and the Northwest Territories. In Quebec, Ontario, Manitoba, Saskatchewan and Alberta, those laws are administered by the provincial governments, while the federal government inspects fish and fishing products produced for sale outside the province.

In British Columbia, the marine fisheries are managed by the federal government, as are the federal laws regarding freshwater anadromous species (fish that migrate to the sea from freshwater). At the same time, the provincial government licenses all inland fisheries and manages all of the other provincial freshwater fisheries.

National Parks fisheries are federally managed. But all freshwater sport fishing outside National Parks is licensed by provincial and territorial governments.

4. Conclusions

Canada's seacoast and inland waters are home to some of the most valued and productive fish stocks in the world. These fish provide food for the world's tables, jobs for our citizens, and a chance to experience the thrill of catching "the big one" on a sunny, summer day.

The fisheries are also inextricably interwoven into the social and cultural fabric of our nation. They support a tradition and a way of life in the many small communities on both coasts and in the North, which is hundreds of years old.

Our natural resources are part of our common heritage. As such, both governments and fishermen together work to conserve this valuable natural endowment and transform it into economic wealth for Canada.

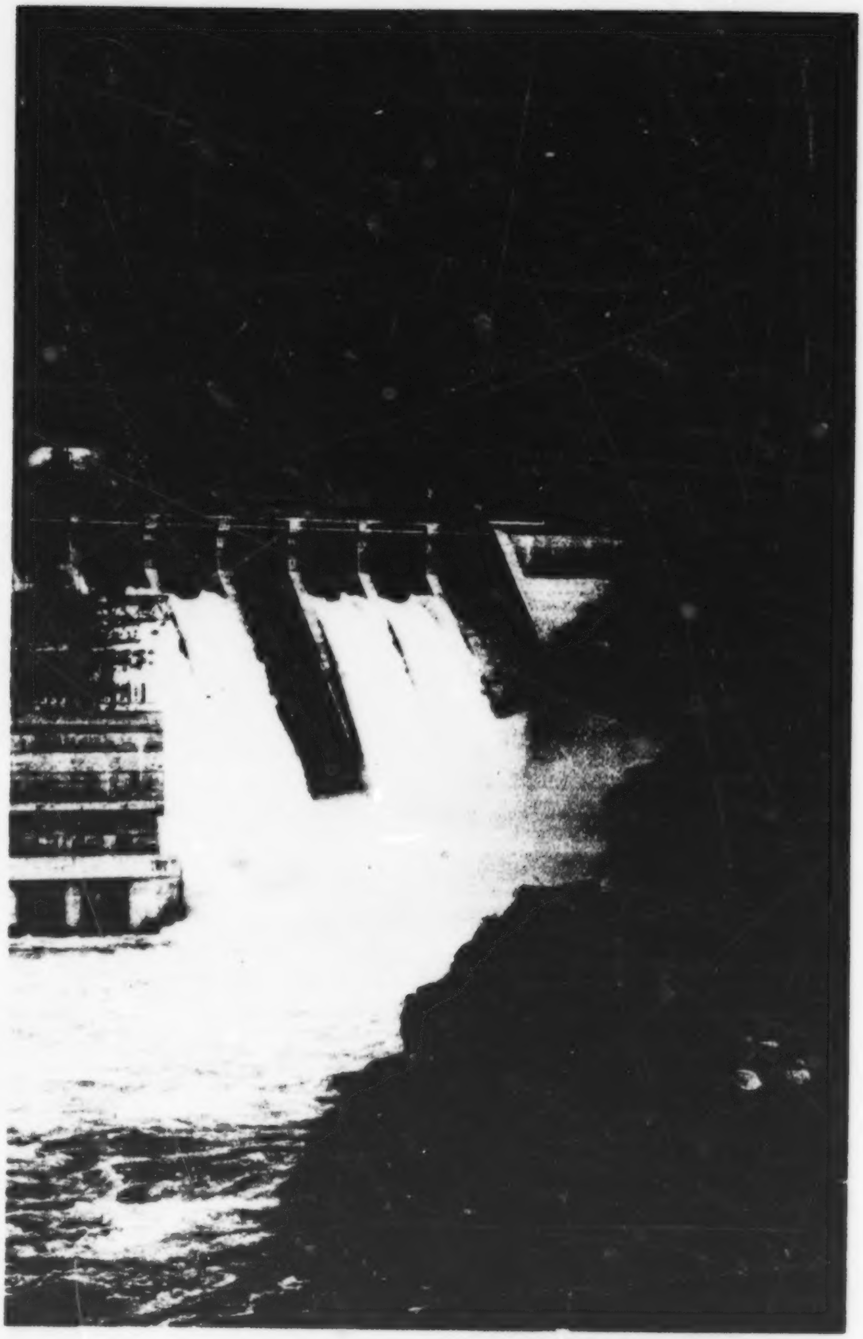
Energy from Water

Introduction

In its 1981 report entitled Energy Alternatives, the Special Parliamentary Committee has said what others have been saying for a long time... "that Canada must place new emphasis on deriving its energy requirements from sustainable sources of energy". While it is true that non-renewable fossil fuels will not be exhausted for some time to come, and that depletion will occur more quickly for some forms than others, Canadians cannot go on indefinitely exploiting fossil hydrocarbons for energy.

In 1978, the relative contributions made by the primary energy forms were: crude oil products and liquified gas 56.5%, natural gas 23.1%, and electricity and coal 20.4%. It is evident, however, that oil's share has begun to decrease and will continue to lose ground to the other major components – natural gas, electricity and coal. This shifting of emphasis away from hydrocarbons is designed to preserve the depleting resources of crude oil, natural gas and coal for such non-energy uses as the production of petrochemicals, and to counter the otherwise formidable environmental problems which are expected to arise in the future if coal becomes a principal element in the energy supply. Possible alternatives to such sustainable energy sources are the sun, wind, biomass and water. Nuclear fuels are also expected to have a role in the future. In 1980, only 15% of Canada's primary energy needs were met by renewable energy sources (10% from hydroelectric and 5% from biomass and solar sources combined).

Among the prospective future energy sources, energy from water (hydroelectric, tidal, wave, thermal gradient and hydrogen) is the most promising and has the largest potential. In the following sections, these energy sources from water are discussed in terms of their technology, prospects, expected future roles, and constraints to their development.



Among the prospective future energy sources, energy from water is the most promising and has the largest potential.

Water – A Renewable Energy Resource

1. Hydroelectric Energy

Hydroelectric energy is the renewable energy inherent in the force of falling water. The capacity to produce this energy is dependent upon both the flow available and the height (head) through which it falls.

The flow, the prime driving force, is continuously replenished by the natural process known as the hydrologic cycle whose prime source of energy is the sun. The development of hydroelectric energy can, in essence, be regarded as an indirect utilization of solar energy.

The head, the distance of vertical fall, can be developed by damming a natural river valley, diverting flow from upstream of a natural waterfall or rapid, or other similar means.

A flow of one cubic metre per second when it has fallen through a 12 metre head produces about 100 kilowatts (kW) of power or 100 kilowatt-hours (kWh) of energy every hour.

Hydroelectric power developments fall into two basic types – storage and run-of-river, with a few pumped storage plants forming a third category.

Storage plants are those involving large storage reservoirs, which store water at times of high flows and release it in a regulated manner to provide power generating capability. These reservoirs are sufficiently large to regulate flows and power output for monthly, seasonal or annual fluctuations. Also, the reservoirs often serve other uses such as flood control, recreation and water supply.

Plants operating largely on natural flows or regulated flows from upstream storage reservoirs are referred to as run-of-river plants. While they may benefit from upstream storage, these plants do not have the capability to regulate flows or power outputs for other than short periods due to the relatively small reservoirs directly associated with them.

Pumped storage plants consist of reversible turbines which pump water to an elevated reservoir for storage during periods of surplus energy. During peak demand, the pumps revert to turbines and utilize the stored water to produce energy.

Table 43

Developed and Potential Hydroelectric Power Capacity in Canada 1981

(Megawatts)

Provinces	Developed	Potential
Newfoundland	6 210	6 152
Prince Edward Island	–	–
Nova Scotia	360	98
New Brunswick	901	556
Quebec	20 771	32 412
Ontario	7 145	6 115
Manitoba	3 641	6 145
Saskatchewan	579	1 505
Alberta	718	11 453
British Columbia	8 785	25 537
Yukon Territory	58	10 440
Northwest Territories	47	6 000
Canada Total	**49 215**	**106 413**

Source: Electric Energy Branch,
Department of Energy, Mines and Resources

Hydroelectric Potential

Canada's total hydroelectric power potential has never been comprehensively investigated, but estimates based on the information currently available are given in Table 43, together with existing generating capacities. This information shows that at the end of 1981 a total of 49 215 MW of hydroelectric capacity had been installed and about 100 000 MW of power potential was still available for development. By the year 2000, total hydroelectric generating capacity is expected to double (Table 47). By then, many of the favourable large scale sites will have been developed. Nevertheless, there will still be a substantial number of large sites, most of which are long distances from the load centres, in difficult locations for construction, or subject to particularly difficult environmental or social implications. These remaining large scale hydro resources are mainly in Quebec, British Columbia, Alberta, Yukon and Northwest Territories, and Labrador.

There remains an undetermined amount of hydro potential which would impose minimum environmental impacts. This hydro potential includes: a) small scale and low-head sites; b) abandoned or decommissioned power sites; c) existing storage or head developed for other purposes (irrigation, recreation, flood control or municipal use, etc.); and d) improving existing older, less efficient, plants. The potential of these environmentally compatible hydro sites in Canada is presently unknown and not included in the remaining undeveloped potential listed in Table 43. Development of these sites has until now been uneconomic because of the competitive cost of electricity generated from fossil-fueled generating plants. However, this situation is changing, and many such previously uneconomic sites are now becoming economically viable as fuel costs rise and as environmental constraints from other sources grow. Environmentally compatible hydro sites are economically attractive especially for providing electricity to remote areas served only by costly diesel generators.

On the one hand, the economic, environmental and social constraints usually limit development of large scale hydro sites. On the other hand, small scale, low-head and existing non-hydro dams or decommissioned hydro sites have unique environmental attributes in that their environmental effects are relatively insignificant as a result of smaller impoundments, less reservoir fluctuation, and smaller scale construction activities. Also, most of the environmental impacts of existing reservoirs have already been incurred and stabilized.

In the United States, a government-supported study indicates that some 50 000 dams have been built for flood control, irrigation and other non-power purposes, of which 19 500 sites could be equipped with small hydro units up to 15 MW. The total capacity of this hydro potential would be about 26 600 MW. While the potential of such hydro sites in Canada is unknown, it would not be too wide of the mark to estimate that this hydro potential might be of the order of 20 000 to 30 000 MW. Much of the discussion in the following section relates to the development of this potential.

New Technology

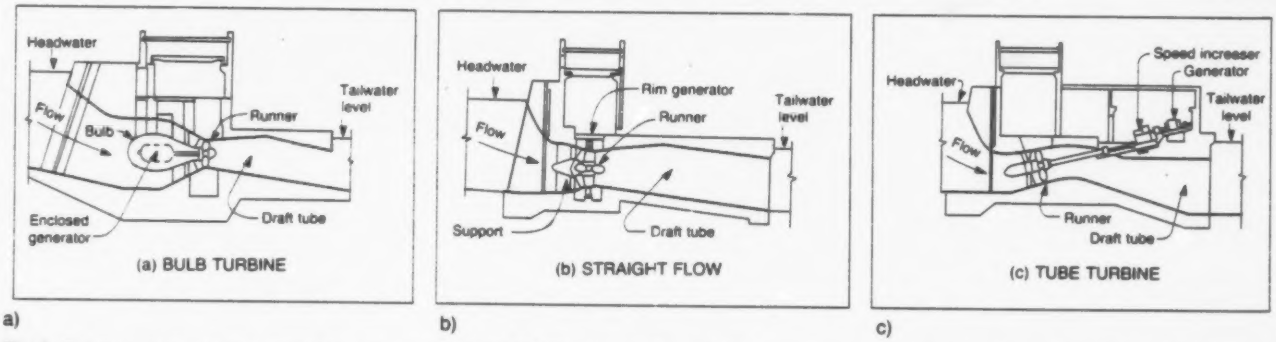
The technology of hydroelectric power developments in Canada is well established and available for immediate use with a long-time successful and reliable operating experience. Nevertheless, there have been some significant new technological developments in hydroelectric power including: a) development and application of low-head horizontal tube turbines and reversible-type bulb or straight-flow turbines; b) standardized design of "off-the-shelf" generating units suitable for small- or mini-scale hydro sites; c) modernization of old power generating units to improve their energy conversion efficiencies; d) application of new system operation and control techniques including remote and microprocessor controls, integration of pumped-storage into the system, transmission interties and computer-aided system optimization; and e) hydrologic simulation techniques used for the sites where flow data are lacking.

Normally, hydroelectric power production benefits and costs vary with the head available. However, when the head is less than a certain limit, governed by the minimum height of vertical turbines and generating

Construction practices and flooding of land associated with hydroelectric projects represent impositions of varying degrees on local populations.

Figure 2

Types of Low-Head Turbines



(a) BULB TURBINE

(b) STRAIGHT FLOW

(c) TUBE TURBINE

a)

The bulb-type generating unit consists of an adjustable blade turbine with a generator contained in a torpedo-shaped casing located in the water passage in a straight horizontal position. By rotating the runner blades, this type of turbine could be made reversible for both flow directions, an ideal arrangement for application to a double-effect tidal power development scheme.

b)

The straight-flow generating unit is a horizontally installed unit with the generator rotor mounted on the periphery of the runner blade tips. By providing a generator with a diameter sufficient for the large number of poles mounted around the outside of the turbine runner and the resulting higher inertia necessary to achieve stable electrical characteristics, this type of unit has several advantages over the bulb-type unit. A straight-flow turbine with a rim-mounted generator has been installed at the Annapolis Royal demonstration tidal plant with the largest runner and generating capacity of this type in the world. If this large demonstration unit (runner diameter: 6.7m, generating capacity: 20MW) performs satisfactorily, especially its sealing and bearing arrangements, this innovative technology may become applicable to low-head plants whether in river or tidal locations.

c)

The tube-type unit is designed to have a water passage with a gently-angled vertical S-shaped bend, and a generator located outside the water passage connected to the turbine by means of an inclined common shaft. The tube turbines may not have quite as high a hydraulic efficiency as the bulb and straight-flow types; however, substantial savings can be achieved in civil works and the units have the advantage of simplicity of design applicable to relatively small scale units.

units which control the power plant height and foundation, and limited by the energy conversion efficiency constraint of turbines, costs tend to become independent of head and benefits decrease. Hydro developments whose heads lie within this lower limit (about 20 metres with conventional vertical turbines) tend to become uneconomical. Such developments could benefit from the new bulb-type, straight-flow rim-type or horizontal tube-type turbines which substantially reduce the major construction costs and improve the turbine efficiencies and hence the overall economy of low-head hydro sites. (Figure 2).

One of the constraints to small scale hydroelectric developments is the higher installation cost per kilowatt than for large scale developments. The higher per unit cost is partly attributable to the costs of site-specific feasibility studies and custom designs for these small projects. This cost disadvantage of small scale hydro projects could be alleviated by standardizing the design, construction method and costing and screening process through documenting actual project developments and demonstration projects. Recent attempts at standardizing generating units should help in reducing the unit cost and development period of small scale projects. With the developed "off-the-shelf" units, engineering design costs can be considerably reduced. Site-specific conditions could make standardization difficult; however, a standard design package for a range of hypothetical site conditions, conceived through research, development and demonstration works, should prove of great value in reducing the overall costs and installation time for such small scale projects.

By raising the efficiency of older less efficient hydro units through rehabilitation or replacement of their turbines with more modern ones, a 10% increase in energy from an individual plant is often feasible, without affecting environmental quality. Actual examples indicate generating capacity can be increased in excess of 30% by simply replacing old turbine runners with ones of new design. The actual potential of increased hydroelectric power generating capacity in Canada attributable to the redevelopment of existing inefficient plants is currently unknown. There are about 800 operating units in Canada which are more than 30 years old, and the potential for increased capacity by improving inefficient units should be significant.

Current technology in remote control and electronic micro-processor control equipment could reduce operating costs through automated, unmanned plant operations. Integration of pumped storage plants into a system, and system-to-system interties, could significantly improve system reliability and flexibility. Modern computerized system engineering technology, together with modern hydrological forecasting technology, could optimize plant operations as well as system planning to realize maximum benefit to the system.

Substantial information on variations in river flows is essential in designing and implementing an optimum hydro site development. An accurate analysis of the extreme events of high and low flows is particularly crucial to the success of a project. The extreme event of low flow establishes the criteria for firm power generating capacity and intermittency of output and even the provision for back-up power sources, especially for an isolated remote plant, while the extreme high flow sets the criteria for spillway capacity and accommodation for floods. For project sites where flow data are lacking, hydrological simulation techniques could be used to generate flow data and establish criteria for an optimum size of the project.

Environmental Impacts

The most noticeable concerns associated with hydroelectric developments are the loss of land and the land-based resources, and wildlife- and fish habitat due to reservoir impoundments; the conversion of wild rivers into regulated rivers or lakes thus modifying the opportunity for fishing, boating, hunting and camping; the barriers dams impose on the migration of fish; and the change in downstream river flow regimes.

Additional, but less noticeable, are the changes in erosion, sedimentation, thermal stratification and water quality, directly or indirectly associated with the developments. There is also a progressive change in the plant and animal composition wherein those which have adapted to a river-type environment are replaced by others which frequent calmer waters. Any diversion from one watershed to another can allow the introduction of foreign biota from one system to the other with effects that can be far reaching.

Construction practices and the flooding of land associated with hydroelectric projects represent impositions of varying degrees on local populations; in some remote areas, these effects can represent a drastic disruption to the traditional way of life especially for native populations.

Economic Aspects

Hydroelectric development has a significant effect economically because, in general, it is more capital intensive than thermal power generation, and becomes even more so as less favourable sites are developed. Large hydro projects involve long planning and construction lead times, high fixed costs but low operation costs. Since capital costs are fixed, they are inflation-proof. The interest rate at the time of construction is the crucial financial factor.

The economics of hydroelectric power development are evaluated on both the investment cost of a hydro project per unit of generating capacity (cost per kW) and unit cost of energy output (cost per kWh). Both of these indices are dictated by the capital cost, interest rate, pay-back period, flow variation and power demand or market. The application of only one of these indices cannot give a full idea of the overall economy of the project. A hydroelectric power project with a unit power cost as high as $2000/kW and a unit energy cost up to 30 mills/kWh is currently marginally acceptable. Some small scale hydro sites, located in remote areas where the alternative would be electricity supplied by diesel generating units, could be economically justified at an even higher cost, perhaps up to $3000/kW and 50 mills/kWh if oil prices continue to escalate. The installation of generating facilities at existing non-power dams or the upgrading of those at retired sites provides economic opportunities for hydro power supply since, in most cases, no major costs for dams are required, and modification or rehabilitation works would be minor compared with new site developments.

2. Tidal Power

The basic principle of tidal power is to convert the potential energy of tidal amplitude (difference between high and low tides) into electrical energy by technology similar to that used in river hydroelectric plants. Generally, a mean tidal range of at least 5 metres is required for technically developable tidal power sites. Besides a tidal cycle, tidal power sites also require physiographic

The Reversing Falls are a phenomenon resulting from the incoming tides which visibly cause the Saint John River to reverse its direction.

conditions suitable for damming and reasonable assurance that physical changes, due to tidal site development, will not substantially reduce the local tidal range.

The gravitational activities of both the moon and the sun on the earth are the forces that influence the tidal amplitudes and cycles, with the moon exerting the greatest influence. Thus, the tidal cycles, which follow the lunar diurnal cycles, occur out of phase with solar days and cause the high tide water level to occur at progressively later times (about 50 minutes) on succeeding days. The tidal cycle is, therefore, out of phase with man's activities which follow the solar cycle.

The tidal range also varies according to the lunar monthly cycle and the relative locations of the moon and the sun with respect to the earth. The highest tides, called spring tides, occur twice a lunar-month (29.5 solar days) at or near the new or full moon when the sun, moon and earth are in line, and the tide-generating forces are additive. The lowest tides (neap tides) of the month occur at the time of the first- and third-quarter moon when the lines connecting the earth with the moon and the sun form a right angle and the influence of the moon and the sun are subtractive. At both equinoxes the tidal ranges are larger than usual. Large differences in tidal ranges occur, however, at different locations along the ocean coasts and estuaries because of secondary tidal waves amplified by the local configuration and physiographic features. For instance, the tidal range of the Bay of Fundy amplifies approximately five times as it progresses from the Gulf of Maine towards the head of the bay as a result of the secondary wave, resonance and the effects of the shelving and narrowing of the bay. The tidal range of the Bay of Fundy, about 18 metres (53 feet), is among the highest in the world.

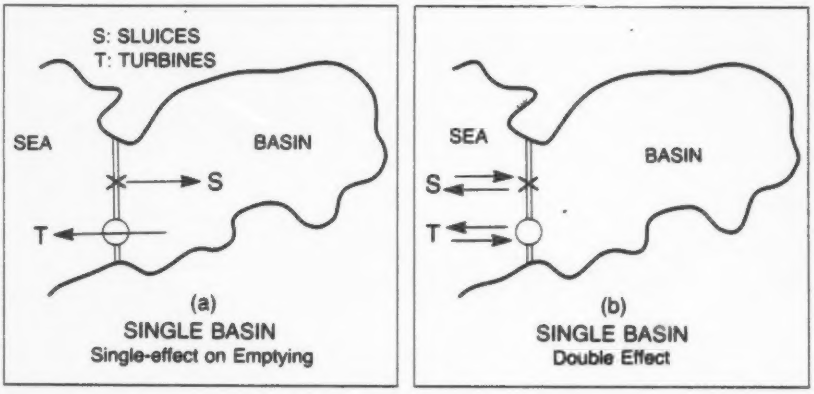
Because the continuously varying magnitudes of local tidal ranges can be accurately predicted, it is possible to forecast with assurance the amount of tidal energy available at any future time scale: hourly, daily, weekly, monthly, or annually. Prediction of the future energy production from a river hydro plant is not nearly as precise as that from a tidal power site.

Concepts of Tidal Development

Tidal power can be exploited by the following basic concepts (Figure 3):

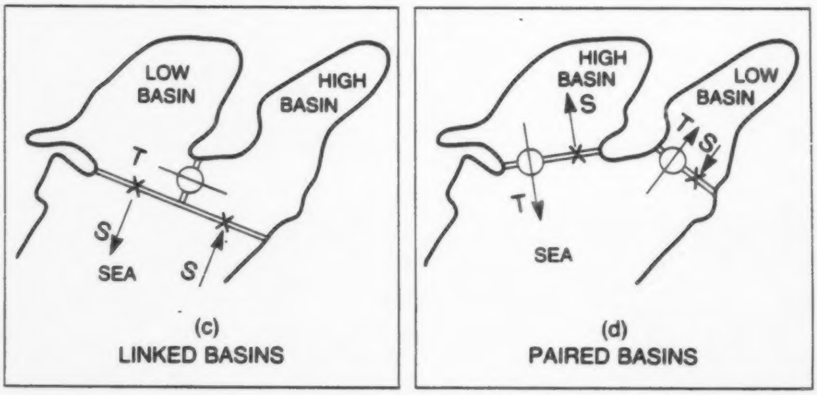
Figure 3

Concepts of Tidal Development



(a)
SINGLE BASIN
Single-effect on Emptying

(b)
SINGLE BASIN
Double Effect



(c)
LINKED BASINS

(d)
PAIRED BASINS

a)

Single-basin with single-effect: In this concept single-effect generating units are used with a single basin to generate in one direction only, usually discharging seaward from the basin during ebb tide. A pumping capability could be incorporated in the units to overfill the basin on the flood tide, thus increasing the head. This concept is the least complex and least costly, but cannot produce continuous power or dependable peak power because the generation is totally dictated by the timing of the tides.

c)

Linked double basin with single-effect system: In this system, one of the two basins is operated as a high basin and the other as a low basin with single-effect turbines which produce power by discharging from the high basin to the low basin. This concept could further prolong the generation times but involves more expensive costs, especially in major works.

b)

Single-basin with double-effect system: The generating units in this system are designed to generate power on both the flood and ebb tides using a single basin. Double-effect pumping may also be included to achieve a greater range between high and low water levels. This concept could partly overcome the generation timing problem of the single-effect system but involves more complex and expensive generating units and civil works. Reversible horizontal shaft turbines are ideal for this concept.

d)

Paired basins with single-or double-effect system: In this system, two or more single basins may be electrically interconnected and operated to take advantage of the time differences in occurrences of high water at different sites.

Through a combined operation with an external pumped storage plant, the shortcomings of tidal plants in matching the energy demand cycle, could be effectively alleviated. The low-value, off-peak portion of the energy output from the tidal plant could be used to pump water up to a storage reservoir where it would be retained pending return of the daily high demand energy cycle.

Generating units with horizontal installations suitable for low-head river hydro plants are directly applicable to tidal power plants. Typical of these horizontal-shaft turbines are bulb, straight-flow and tube turbines which could considerably reduce foundation costs in comparison to the conventional vertical shaft turbines as discussed in the preceding section on hydroelectric power plants.

The world's first large tidal plant was commissioned in 1967 at the LaRance estuary near the Gulf of Saint-Malo, in France. This 240 MW, (24-unit) plant uses bulb-type reversible generating units and operates in both tidal directions at tidal ranges up to 13 metres. Also, a small-scale 400-kW prototype experimental tidal plant was installed in 1968 at Kislaya Gulf on the White Sea, in Russia. China operates a 500-kW experimental tidal power plant at Yuequing Bay on the Eastern China Sea.

In Canada, investigation of the feasibility of harnessing the tidal power of the wholly Canadian portion of the Bay of Fundy was initiated in the early 1940s. A demonstration tidal plant was brought into operation in 1984 in the existing Annapolis Royal causeway near the mouth of the Bay of Fundy. This joint project, funded by the governments of Canada and Nova Scotia, is expected to provide valuable data on both the technical and environmental aspects associated with future full-scale tidal developments in the bay as well as low-head river hydro sites.

Major obstacles to tidal power developments are the very high initial capital investment and the lack of practical experience in their development.

Tidal Power Potential

In addition to the Bay of Fundy, which is known to have one of the highest tidal ranges and the most promising tidal sites in the world, there are a number of other potential tidal sites in Canada. Included are Jervis-Sechelt Inlet and Observatory Inlet on the coast of British Columbia, Ungava Bay in Northern Quebec, and Hudson Bay and Frobisher Bay on Baffin Island. Of these tidal sites, however, only the Bay of Fundy and Jervis-Sechelt Inlet sites have any chance of transmission system interconnection or substantial local power demands in the foreseeable future.

At the time of the recent Fundy Tidal Power Development study, three sites were selected for detailed consideration out of an initial 37 sites. The three sites are expected to be able to generate an annual average energy of 20 609 GWh from their total combined potential of 6435 MW. This annual energy generation figure is about 30% larger than the combined energy needs of both Nova Scotia and New Brunswick in 1980. Capacity and energy output and capital costs of the three tidal sites are shown in Table 44.

The combined use of tidal power generation with pumped-storage power plants and hydrogen by off-peak energy could enhance the economy of tidal power plants. Tidal power in Canada, however, is not expected to be developed in the next ten years except for the current demonstration plant at Annapolis Royal. The future of the Bay of Fundy tidal power development will be reassessed based on technical, economic and environmental data to be obtained upon the completion of the Annapolis Tidal Power Demonstration Project.

Environmental and Social Impacts

The major environmental concerns of a tidal power development are the impacts which the barrage and the plant operation can impose on fish migration, changes in the tidal cycle and magnitude, modifications to the coastal and bottom erosion and sedimentation patterns, changes in salinity. stratification, and possible effects on upstream flooding if the barrage is located in an estuary of a river.

Unlike hydroelectric developments with large reservoirs, the social impacts of tidal power developments do not appear to be of great significance. This is because no reservoir inundation is involved except some alteration of tidal water levels which could adversely affect the groundwater table and salinity of the coastal farm lands. Nevertheless, temporary manpower movements and a shift of social structures in the vicinity of the development site during construction could be significant.

Tidal Power Constraints and Prospects

The immense capital requirement is the main constraint to tidal power development. A 1085 MW station at Cumberland Basin in the Bay of Fundy, for instance, would cost in excess of $1.2 billion (1977 dollars). As other energy costs (oil, gas or coal) escalate, tidal power could become a more economical proposition, perhaps near the end of the century. Its contribution to the future energy system, however, would be regional.

Table 44

Capacities, Energy Outputs, and Capital Costs of Three Tidal Power Sites in the Bay of Fundy

Tidal Sites	Installed Capacity (MW)	Annual Output (GWh)	Capital Cost (millions of 1977 dollars)
Shepody Bay	1 550	4 533	2 197
Cumberland Basin	1 085	3 423	1 234
Cobequid Bay	3 800	12 653	3 988
	6 435	20 609	7 419

3. Ocean Wave Energy

Wave energy can be thought of as a concentrated form of wind energy. The ocean acts as a giant wind power collector absorbing wind energy over vast areas and concentrating it in the form of waves. Devices for the extraction of the wave energy fall into two categories: mechanical and hydraulic. Mechanical devices convert wave energy into electric energy mechanically by use of a string of rafts which use the rolling and rocking motion of waves. Hydraulic devices generate electric energy through air-driven turbines by the use of compressed air built up by oscillations of waves trapped in an inverted sealed cylinder or massive rectangular structure floating in the sea with the bottom side open to the waves.

This system has already been used as a power source in navigation buoys and in an experimental wave power generation ship called "Kaimei" (1 MW generating capacity) in Japan. A recently developed flexible bag concept at Britain's Lancaster University generates electricity through two-way air turbine generators by use of the compressed air in and out of the huge rubber membrane breakwater against which wave trains exert pressure.

An innovative wave energy generating device could be developed by combining a massive rectangular structure and a flexible bag installed at its periphery. This combined device could use two-way air turbines to generate electric energy by use of compressed air built by both the oscillations of waves inside the massive structure and the pressures exerted by the wave trains against the membrane surrounding the structure. This device could also be used in combination with other purposes such as an off-shore drilling platform, air strip or deep-water mooring facilities. These off-shore structures could especially benefit from the flexible bag wave energy generator which absorbs the often destructive wave forces.

In many countries there is an increasing interest in the possibility of harnessing the power from the oscillating ocean wave motions. The International Energy Agency has put a wave energy research and development (R&D) program into action by designating Britain as a lead agency. In the R&D program, various wave energy collector systems are to be investigated and technical problems are to be examined. In Canada, under the auspices of the Interdepartmental Task Force on Energy R&D, the National Research Council is currently investigating the future of wave energy in a Canadian context including the technology and magnitude of the Canadian wave power resources. These investigations have indicated that the amount of exploitable wave energy in Canada is small and spread over a wide area compared with that of other countries such as Britain, Norway or South Africa.

Exploiting wave energy potential in Canada would require decades of concentrated effort in solving a number of technical and economic problems such as the development of wave machines of sufficient efficiency, acceptable cost and reliability in the rigorous and corrosive marine environment; the methods of mooring such machines at a considerable distance from shore and in deep water, perhaps off the continental shelves; and a method for transmitting the electric energy to shore. Despite these technical and economic problems, wave energy is expected to become a practical proposition and eventually will contribute at least in a minor way to Canada's intermediate or long-term energy demands as a renewable energy resource.

The development of power sites exploiting wave energy requires ice-free waters with waves of sufficient height and constancy. In Canada, waters off the west coast have the greatest potential while development in east coastal waters is limited by winter ice. The average annual wave power potential expressed in kilowatts per metre width of wave crest has been estimated for the following three locations:

- Tofino, British Columbia – 35.1 kW/m

- Western Head, Nova Scotia – 12.1 kW/m

- Logy Bay, Newfoundland – 27.6 kW/m

The Tofino site could operate throughout the year with 70% of the wave power potential occurring during the winter months November to March inclusive. At Logy Bay a similar percentage of the wave power could be expected to occur during the same five months but sea ice would often preclude operation during the period February to May.

Environmental Impacts

The environmental impacts from wave energy development are not of as great a concern as those of hydro or tidal power developments since most of the currently developed wave energy conversion technologies involve floating structures which cause few changes in the environment.

The ocean acts as a giant wind power collector absorbing wind energy over vast areas and concentrating it in the form of waves.

4. Thermal Gradient Energy

Acting as giant solar energy receptors, the earth's oceans store solar radiation in the form of heat in their surface waters. Because of the density difference between warm and cold waters, oceans become thermally stratified with the lighter warm water remaining on top. Using this temperature difference, it is possible to generate electricity through turbines by evaporating water or some other working fluid such as ammonia, propane or fluorocarbons. An active research and development program is under way in the United States concerning this concept, known as OTEC (Ocean Thermal Energy Conversion).

Converting the ocean thermal energy into electricity normally requires a temperature difference of at least 18°C. Near the earth's equator in the tropical zone, an exploitable temperature difference always exists between the surface and waters 500 to 1000 metres deep. Because of the low efficiency of OTEC plants (typically only 4% or less), very large amounts of warm water and cold water must be circulated to extract the energy and, both a large facility and large investment are required.

In Canada, it isn't feasible to use ocean temperature differences for energy conversion but it may be feasible to extend the OTEC concept to deep freshwater lakes where substantial differences exist between surface and bottom water layers. However, while most Canadian freshwater reservoirs sustain a wide temperature range during the summer, water temperatures are much more uniform for the other seasons following an overturning and mixing stage which takes place in the fall. During summer stratification periods temperature differences of 15° or more are not unusual in deep freshwater lakes or artificial reservoirs behind dams. In Lake Ontario, the surface water temperature is normally 20°C with bottom water temperature at 4°C during summer stratification. The vertical distances between these two extreme temperature water layers in freshwater lakes or reservoirs are much less than in the ocean, and the corrosive salt water problem does not exist in the freshwater environment. These facts offer some advantages for extending the OTEC concept to freshwater conditions under lower temperature differences.

According to theoretical calculations, an enclosure with a surface area of about 1000 m² is required to extract 1 kilowatt of power by OTEC. Extracting 1000 MW of power from Lake Ontario, for instance, with the extreme temperatures of 20°C and 5°C, requires a net volume of about 4000 m³/s of pumped water from lower levels and about 1000 km² of surface area.

The total average flow and surface area of Lake Ontario are about 7000 m³/s and 20 000 km² respectively, indicating that about 60% of the total flow and 5% of the total lake surface area are necessary to provide a 1000 MW thermal energy potential from Lake Ontario.

As a considerable amount of heat is discharged to the Great Lakes from thermal electric power plants, thermal gradient energy conversion could profit from the waste heat which is normally discharged to the surface layer of the lakes forming a year-round thermal plume surface layer.

Environmental Impact

Thermal gradient energy development could impose some water quality problems due to the large amounts of water circulating between the lower depths and the surface. The water circulation could result in an imbalance in the lake ecosystem during summer stratification periods by lowering the thermocline, the layer in a lake in which the temperature gradient is relatively large.

5. Hydrogen Energy

Hydrogen (H_2), one of the most abundant elements in the universe, promises to be an important fuel in Canada's future energy system. It is always found combined with another element or elements, for example, water H_20 or methane CH_4. In order to obtain pure hydrogen, energy must be spent to separate it from its other elements; this is why hydrogen should not be referred to as an energy source. It is an energy carrier or currency, however, as it releases energy upon recombination with oxygen. Hydrogen is in fact a highly desirable energy currency since it can be produced from a wide variety of sources. It can be generated through a number of processes and applied to a broad range of uses.

The main consumer of pure hydrogen is the chemical industry which uses hydrogen as a raw material in the manufacture of commodities ranging from plastics to fertilizers. The petroleum refining industry also uses large quantities to upgrade oils. Pure hydrogen is also an alternative fuel because it has the highest energy density per unit weight of any chemical fuel and because virtually the only by-product of its combustion in air is water.

H_2 is already in limited use in some countries to fuel urban transit systems and it is also well suited for use as an aircraft fuel because of its high energy content. Residential heating systems, appliances and passenger cars can also be converted to use hydrogen.

Hydrogen can be produced by a number of conversion techniques including: a) electrolysis from water; b) water-gas reaction; c) thermal decomposition; d) thermochemical process; and e) photochemical process. Of these, the electrolysis process is the most promising and practical method, involving only water and electricity. Currently, the electrolysis process generates less than 1% of Canada's total hydrogen needs, with the water-gas reaction process supplying most of the demand.

Hydrogen separation by electrolysis involves direct current electricity passing through a solution of water and a catalyst which causes the water to decompose into its chemical components, hydrogen (H_2) and oxygen (O_2). One of the largest commercial electrolysis plants in the world is in operation at a Cominco plant in British Columbia generating hydrogen used in the production of ammonia-based fertilizers. This plant has a process efficiency of the order of 65%.

Other hydrogen conversion techniques, such as thermal decomposition, thermochemical and photochemical processes, are still in the research and development stage and their technical and economic viability have yet to be determined. Canada's main effort in hydrogen production, therefore, is expected to remain with the electrolytic process given Canada's abundant supply of water and electricity. Use of electricity generated from remotely located hydro sites (large or small scale), tidal power plants and large scale nuclear power plants to generate hydrogen by the electrolysis process seems particularly attractive in Canada for technical and economic reasons.

The possibilities for hydrogen production from water in Canada can be considered to be unlimited because hydrogen could be produced from both the abundant resource of fresh water as well as from the unlimited resource of sea water. Therefore, hydrogen should prove ideal in many ways to replace finite hydrocarbon fuels, especially in Canada.

Wave, Thermal Gradient and Hydrogen Energy Potential

The energy conversion technologies of wave, thermal gradient and hydrogen are still in the research and development stage except for some limited commercial production of hydrogen for industrial applications. The economic and social aspects of these energy alternatives are, therefore, still unknown. The contribution from wave and temperature gradient energy in the medium or long term energy picture is expected to be limited. Hydrogen energy, however, could contribute a considerable share to the nation's future energy system depending upon political and environmental concerns. The overall economy of the energy system, especially the electric energy system, could be considerably upgraded once the hydrogen technology is technically and economically proven to be feasible. The econony of untapped remotely-located large scale hydro sites, currently uneconomic due to high transmission costs, could be enhanced by producing hydrogen at site.

Hydrogen production by use of low-value, off-peak electricity generated from hydro, nuclear or future tidal power sources could also considerably improve the overall economy of an electric energy system. Replacement of hydrocarbon fuels by hydrogen could contribute positively by saving shrinking oil reserves for more important uses in the petrochemical industry. Costs of hydrogen production, which depend on the cost of electricity and the type of process used, currently range from $40 to $80 per barrel of oil equivalent energy value.

Water Supply Constraints to Energy Development

Security of energy supply has substantial implications for Canada's water resources development. This is especially so in the prairie region, the location of much of Canada's exploitable reserves of oil and coal, chronic water shortages, and intense competition between alternative water uses. Ultimate self sufficiency may depend in large degree upon the availability of adequate water supplies.

Already, water shortages during low flow periods, and the impact of water constraints have had implications for long-term investment in power generation facilities. Further development of thermal power sites in Alberta will likely require continued adoption of recycling water systems, the use of cooling ponds or towers, or water imports. Availability of cooling water poses a significant constraint to coal-fired thermal power developments in southern Saskatchewan. This may force a switch to more costly dry cooling systems, transportation of coal to areas where water supply is more abundant, or water imports.

Such major developments in the power generation and agricultural sectors will have interdependent impacts on the planning and development of all other water uses in the immediate basin and especially in downstream reaches.

Major decisions will have to be made with respect to the location of economic activities, appropriate water use and conservation technology, and the development of large-scale storage and possibly interbasin water transfer projects. Irrigated agriculture, and thermal and hydroelectric power developments will significantly influence, and be influenced by, these decisions.

Although the need for information on water supply constraints to energy development has been identified as one area that needs immediate attention, water supply for energy development cannot be considered in isolation. Any energy-related study of water use must take into account other present and potential uses of available water supplies.

For this reason, the Department of Energy, Mines and Resources has commissioned the Inland Waters Directorate of Environment Canada to oversee a study of water supply constraints to energy development. The overall purpose of the study is to develop methodologies and data bases with which to examine potential water use conflicts or shortages in river basins within Canada, with particular reference to energy developments.

Phase 1, an overview study of basic data identifying regions where water use constraints are likely to occur, has already been undertaken. This phase, which incorporates information on proposed energy developments in Canada to the year 2000, identified areas likely to come under increasing water stress over the next few years, based on this single projection of water use.

Phase 2, which also has been undertaken, examined emerging water needs in the important water using sectors of the economy, namely municipalities, mining, energy development, manufacturing and agriculture. It included the development of a water use forecasting model capable of identifying the effects of population and economic growth, technological changes and other factors on water use. The report on this phase includes a case study of water supply demand in the South Saskatchewan River basin.

Electric Power Development – 1981

In 1981, total electrical energy production rose to 377 624 GWh, about 2.8% more than the total for 1980. Hydroelectric sites accounted for 70% of the 1981 production, nuclear plants produced another 10% and the remaining 20% was from conventional thermal sources.

A major event during 1981 was the completion of the last five 333 MW units at Quebec Hydro's La Grande Site 2 (LG-2) project. The LG-2 site, with a total generating capacity of 5328 MW, is now the largest generating station in Canada, surpassing the 5225 MW at Churchill Falls, Newfoundland. Two other hydroelectric sites (LG-3 and LG-4), with capacities totalling 5941 MW, are scheduled for completion in 1985.

Nuclear generation became the largest contributor to Ontario's electrical supply in 1981 when 37 799 GWh of nuclear energy was generated, compared with hydroelectric (37 335 GWh) and conventional thermal (34 906 GWh).

As indicated in Table 45, British Columbia, Manitoba, Quebec and Newfoundland obtain almost all of their electricity from hydroelectric generating plants. At present, electricity generated in Alberta, Saskatchewan, New Brunswick, Nova Scotia and Prince Edward Island is primarily from fossil-fuelled generation (coal, oil and gas). The Province of Ontario currently obtains almost equal amounts of energy from each of hydroelectric, fossil-fuelled (mainly coal), and nuclear sources.

All electrical energy generated in a province may not be consumed in that province. A

Hydroelectric plants like this one accounted for 70% of Canada's electrical generation in 1981.

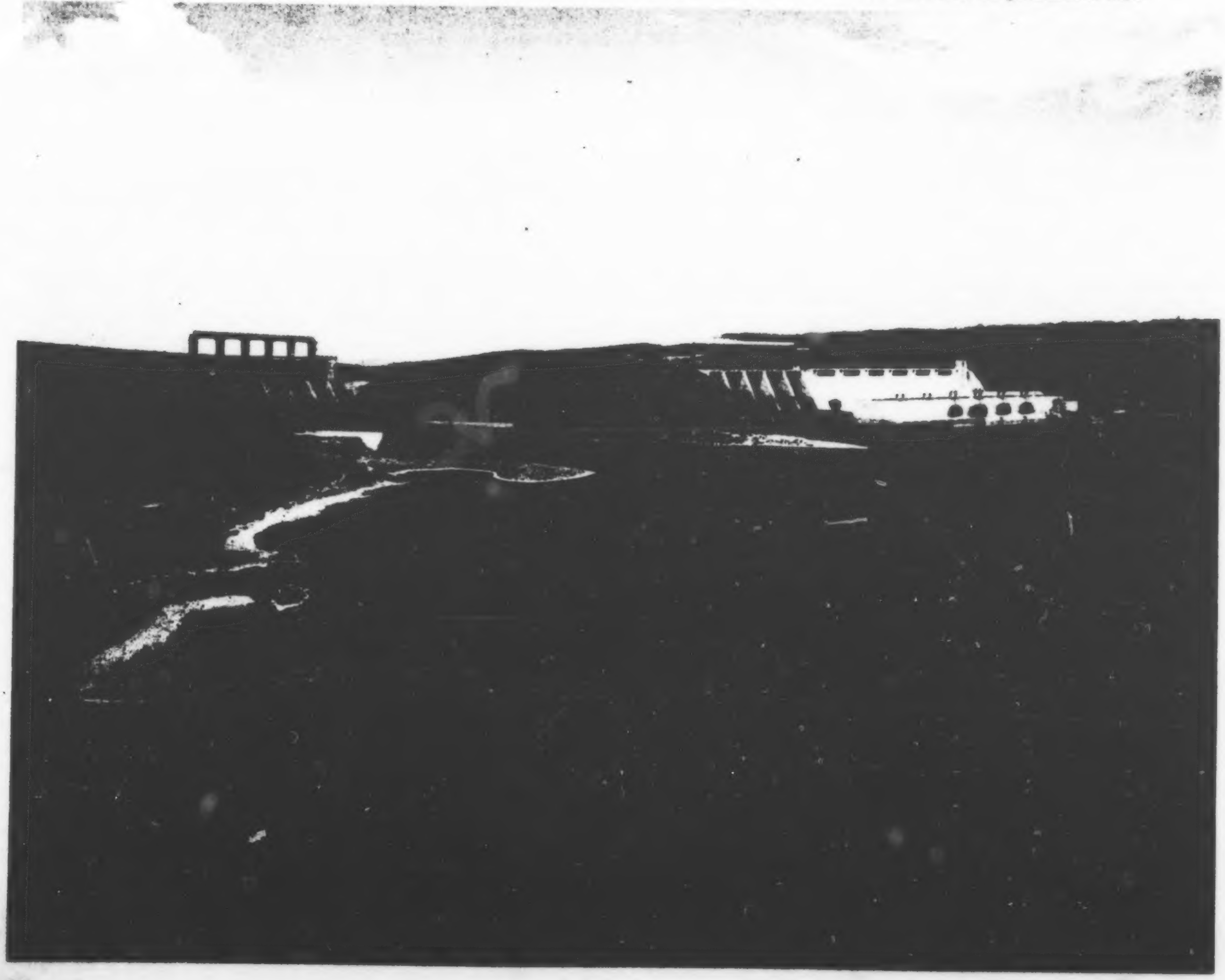


Table 45

Electric Generating Capacity (MW) and Output (GWh) – 1981

(c): Capacity in MW
(o): Output in GWh

Provinces		Hydro	Thermal		Total
			Conventional	Nuclear	
British Columbia	(c)	8 785	1 740		10 525
	(o)	49 408	1 597		51 005
Alberta	(c)	718	5 464		6 182
	(o)	2 035	22 461		24 496
Saskatchewan	(c)	579	1 761		2 340
	(o)	3 097	6 576		9 673
Manitoba	(c)	3 641	501		4 142
	(o)	17 899	532		18 431
Ontario	(c)	7 145	13 242	5 600	25 987
	(o)	37 335	34 906	37 799	110 040
Quebec	(c)	20 771	1 184		21 955
	(o)	102 730	176		102 906
Newfoundland	(c)	6 210	750		6 960
	(o)	44 212	454		44 666
New Brunswick	(c)	901	1 894		2 795
	(o)	3 830	5 105		8 935
Nova Scotia	(c)	360	1 669		2 029
	(o)	1 167	5 402		6 569
Prince Edward Island	(c)	–	118		118
	(o)	–	31		31
Yukon Territory	(c)	58	36		94
	(o)	290	102		392
Northwest Territories	(c)	47	133		180
	(o)	250	230		480
Canada Total	**(c)**	**49 215**	**28 492**	**5 600**	**83 307**
	(o)	**262 253**	**77 572**	**37 799**	**377 624**

Source: Electric Power in Canada 1981.

considerable amount of electricity may be transferred between provinces or exported to the United States. This trend to electricity transfers and exports is expected to continue in the future and to increase. As shown in Table 46, the interprovincial transfers in excess of 1000 GWh in 1981 were from Newfoundland to Quebec, Quebec to Ontario, Manitoba to Ontario, and Quebec to New Brunswick. The major exports to the United States in 1981 were from Ontario, British Columbia, Quebec, Manitoba and New Brunswick. Altogether, about 9% of Canada's total electric energy was exported to the United States in 1981, for a total net revenue exceeding $1.1 billion.

There are a number of provinces where increased power exports are possible, and may be advantageous; for example: Manitoba has underdeveloped northern hydro resources plus present surplus capacity, and could export more to the north-central states, as well as gain through exchanges; the Atlantic provinces could export to New England – possibly for a period up to ten years from the larger nuclear unit at Point Lepreau, and also from new hydro or tidal developments in nearby areas; a Quebec and Labrador interconnection could export surpluses to New York and the eastern central Atlantic region, as well as engage in profitable exchanges; and New York and the eastern central Atlantic area could be an enhanced five- to ten-year firm power market for Ontario energy, providing capacity installation is not discouraged and transmission capacity is enlarged.

Forecasting Electric Demand

Forecasting the future demand growth is a most difficult and critical task of the electrical utility industry which is responsible for meeting the electricity demand across Canada. Since demand forecasts almost always deviate from the actual demand, especially for a long-term projection which is required for most major developments, utilities have a policy of updating their forecasts annually and maintaining flexibility of actual development schedules. Generally, they tend to maintain excess capacity rather than under-installed capacity because it avoids system service interruptions and maintains the system reliability; it is easier and less costly to delay a construction schedule than to accelerate it; and energy production in excess of system needs can usually be sold to neighboring systems, thereby offsetting the costs of over-investment.

Table 46

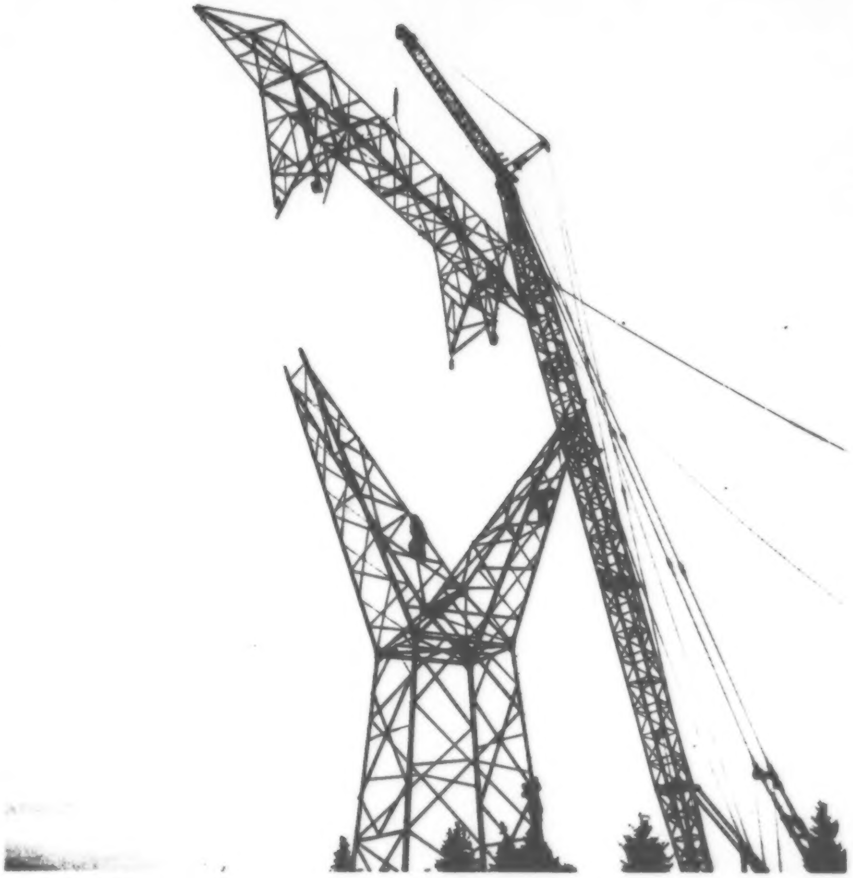
Electricity Imports and Exports – 1981

In gigawatt hours

	Interprovincial		International		
	Exports	Imports	Exports	Imports	Net Export or (Import)
British Columbia	165	262	8 821	897	7 827
Alberta	262	168	–	2	92
Saskatchewan	1 068	1 290	–	–	(222)
Manitoba	2 508	1 066	3 681	194	4 929
Ontario	60	7 705	11 310	343	3 322
Quebec	10 208	36 098	8 313	7	(17 584)
Newfoundland	36 039	–	–	–	36 039
New Brunswick	801	3 846	3 246	54	147
Nova Scotia	125	317	–	–	(192)
Prince Edward Island	–	484	–	–	(484)
Yukon Territory	–	–	–	–	–
Northwest Territories	–	–	–	–	–
Total	**51 236**	**51 236**	**35 371**	**1 497**	**33 874**

Source: Electric Power in Canada 1981

Table 47 indicates the electric generating capacity forecast for 1990 and 2000 based on information provided by utilities and the National Energy Board. Note that the ratio of hydroelectric capacity to total capacity is expected to increase from 59% in 1981 to more than 62% in the year 2000, indicating that hydroelectric energy will retain its dominant role in electric energy production for decades to come.



Transmission line development for purposes of electric power transfers between provinces and export to the United States is expected to continue and to increase.

Table 47

Forecasts of Generating Capacity by Type

in millions of kilowatts

	Conventional Thermal					
	oil	gas	coal	nuclear	hydro	Total
1981*	8.0	4.5	16.0	5.6	49.2	83.3
1990	10.6	3.7	20.7	15.5	66.7	117.2
2000	11.3	3.9	24.2	19.2	96.6	155.2

*actual

Source – Electric Power in Canada 1981.

The Canadian Heritage River System

In 1979, officials of the federal, provincial and territorial governments began work on the development of the Canadian Heritage River System (CHRS) in order to provide a vehicle for the recognition and conservation of those rivers deemed to be of outstanding Canadian heritage value. The inclusion of such rivers in a single coast-to-coast system would allow for the management of these rivers in a manner that would protect their significant heritage values as well as provide opportunities to the public for appreciation and recreational enjoyment.

Following two years of discussion, a report was produced disclosing the collective viewpoints of all governments and outlining how a Canadian Heritage River System could best be established and operated.

On January 18, 1984, the creation of the CHRS was announced, with the federal government, five provinces – Saskatchewan, Manitoba, Ontario, New Brunswick, Nova Scotia and Newfoundland – and both territories taking part. Nova Scotia joined in May 1984. The federal government, through Parks Canada, is providing administrative and technical support.

Guidelines for the Selection of Canadian Heritage Rivers

A river will be included for selection to the Canadian Heritage Rivers System if it meets one or more of the "Heritage Value Guidelines", as well as a set of "Integrity Guidelines" (Tables 48 and 49 illustrate these guidelines).

While no formal limit will be imposed either on the total number of rivers included in the System or on the number of rivers any individual jurisdiction can nominate for inclusion, the purpose of the System is not to provide for the conservation of all rivers of interest, importance or value, but only for the most outstanding of these from a Canadian viewpoint.

The CHRS is a cooperative program in which federal, provincial and territorial governments, while participating in the administration of the CHRS, retain their traditional jurisdictional powers, including ownership of land, the choice to nominate a river to the CHRS, and the right to continue to operate and manage designated rivers in accordance with the objectives of the CHRS. In keeping with the cooperative spirit of the CHRS, the nomination of an international river would be preceded by suitable consultation with U.S. representatives.

Since 1977, officials of the federal, provincial and territorial governments have worked to develop the Canadian Heritage River System, a vehicle for the recognition and observation of those rivers deemed to be of outstanding Canadian heritage value, or unique to a province or territory.

Table 48

Value Guidelines for Selection of Canadian Heritage Rivers

Natural Heritage Values

Outstanding Canadian natural heritage value will be recognized when a river environment meets one or more of the following guidelines:

- It is an outstanding example of a Canadian river environment affected by the major stages and processes in the earth's evolutionary history. This would include rivers which best represent the major periods of geological time in which the surface of the earth underwent major changes and stream modification;
- It is an outstanding representation of significant ongoing fluvial, geomorphological and biological processes. As distinct from the periods of the earth's development this focuses upon ongoing processes in the evolution and form of the river and its associated plant and animal communities;
- It contains along its course unique, rare or outstanding examples of natural phenomena, formations or features, or areas of exceptional natural beauty;
- It contains along its course habitats of rare or endangered species of plants and animals, or areas where outstanding concentrations of plants and animals of Canadian interest and significance are found.

Human Heritage Values

Outstanding human heritage value will be recognized when a river environment meets one or more of the following guidelines:

- It is of outstanding importance, over a period of time, to the historical development of Canada owing to its impact upon the region which it influences; this would include its role in such significant historical themes as native people, settlement patterns and transportation;
- It is strongly associated with persons, events, movements, achievements, ideas or beliefs of Canadian significance.
- It contains historical or archaeological structures, works or sites which are unique, rare or of great antiquity;
- It contains outstanding examples or concentrations of historical or archaeological structures, works or sites which are representative of major themes in Canadian history.

In every case consideration should be given to the state of preservation of the river environment relative to its visual appearance during the historic period in which the waterway is considered to be of outstanding importance.

Recreational Values

Outstanding recreational value will be recognized when a river environment meets the following general guidelines:

- It possesses an appropriate combination of recreational opportunities (boating, hiking, swimming, camping, wildlife viewing and human heritage appreciation) and related natural values (natural visual aesthetics such as diversity and quality of scenic beauty, as well as physical essentials such as sufficient flow, navigability, rapids, accessibility and suitable shoreline) which collectively provide a capability for an outstanding recreational experience.
- It is capable of supporting recreational uses without significant loss of or impact on its natural, historic or aesthetic values.

Table 49

Integrity Guidelines for Selection of Canadian Heritage Rivers

- The river and its immediate environment should be of sufficient size and contain all or most of the key interrelated and interdependent elements to demonstrate the key aspects of the processes, features, activities or other phenomena which give the river its outstanding value;
- The river and its immediate environment should contain those ecosystem components required for the continuity of the species, features or objects to be protected;
- The quality of the water should be such as to provide for the continuity and/or improvement of the resources upon which 'value' to the system has been determined.

The inclusion of heritage rivers in a single coast-to-coast system will allow for the management of these rivers in a manner that should protect their significant heritage values as well as provide opportunities to the public for appreciation and recreational enjoyment.

The Canadian Heritage Rivers Board

The Board is comprised of two representatives from the federal government (Parks Canada and Indian and Northern Affairs) and one from each of the provincial and territorial governments choosing to participate in the program.

The Board's main function is to make recommendations to the ministers responsible for Parks Canada and the managing government agency on the designation of rivers. It also develops public awareness of the CHRS, encourages the nomination of rivers for inclusion in the CHRS, and monitors the status of designated rivers. The Board may also recommend removal from the CHRS of any river which no longer fulfills the objectives of the CHRS.

General Steps Leading to Designation

An agency – federal, provincial or territorial – conducts research to identify and assess the significance of the natural, human and recreational resources of a river within its jurisdiction. The agency then presents a nomination document when it is ready to have the river incorporated into the CHRS.

After reviewing the nomination to determine if the river meets the guidelines, the Board will either accept the nomination or return it to the submitting agency.

A river whose nomination has been accepted becomes a "Candidate Canadian Heritage River" pending the submission of a management plan to the Board. Upon receipt of the management plan, which must be lodged within three years of the nomination, the Minister responsible for Parks Canada and the minister(s) of the nominating agency(ies) will formally designate the river to the Canadian Heritage Rivers System.

The Management Plan

The management plan establishes the boundaries of the river management area and sets out the policies and practices to be followed by the managing agency to ensure that plans for development, management and use of the river are consistent with the objectives of the System. In this way, the management plan demonstrates the commitment of the nominating jurisdiction to protect the river's heritage values. The specific contents of the management plan are the prerogative of the managing agency and will not be approved or disapproved by the Board.

Table 50

Rivers Nominated to the Canadian Heritage Rivers System

January 1, 1985

River	Location	Nominee
Alsek	Yukon	Parks Canada
South Nahanni	Northwest Territories	Parks Canada
Athabasca	Alberta	Parks Canada
North Saskatchewan	Alberta	Parks Canada
Clearwater	Saskatchewan	Saskatchewan
Bloodvein	Manitoba	Manitoba
French	Ontario	Ontario
St. Croix	New Brunswick	New Brunswick

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